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ECP Passenger Cable-Based Braking System—Performance Requirements

Abstract: This standard contains the minimum performance requirements for electronically controlled pneumatic (ECP) brake systems operating on passenger cars that are part of the general railroad system.

Keywords: brake, ECP, railcar, train

Summary: This standard was titled "Electronically Controlled Pneumatic Cable-Based Braking System — Performance Requirements for Passenger Applications" in the previous publication of this document. This document identifies the minimum performance requirements for the operation of ECP brake systems on passenger train equipment. This standard addresses functional performance measures for each operating mode of an ECP brake system, establishes interoperability between freight and passenger systems, and defines fault response and recovery functions. It is to be used with APTA PR-M-S-020-17, latest revision, "Passenger Electronic 26C Emulation Braking System – Performance Requirements."

Scope and purpose: This document identifies differences in functionality between passenger rail ECP applications and Association of American Railroads S-4200 freight applications, retaining elements of S-4200, "Electronically Controlled Pneumatic (ECP) Cable-Based Brake Systems—Performance Requirements" applicable to passenger trains and adding new requirements specific to passenger trains. This standard ensures that APTA-approved ECP brake systems from different manufacturers are interoperable and that they meet a high level of safety and reliability. The overall objectives of this standard are to define functional requirements specific to U.S. trains operating in passenger service equipped with ECP; to ensure that trains equipped with APTA-approved ECP brake systems from different manufacturers are interoperable and function consistently and uniformly; and to ensure that APTA-approved electronic brake systems meet a high standard for safety and reliability.

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Introduction

This introduction is not part of the standard requirements of APTA PR-M-S-021-17, Rev. 1, "ECP Passenger Cable-Based Braking System—Performance Requirements," (Electronically Controlled Pneumatic Cable-Based Braking System — Performance Requirements for Passenger Applications).

Sections 2. through 2.5.2.6 inclusive are codified in 49 CFR 238.

This standard applies to all:

1. Railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and

2. Railroads that provide commuter or other short-haul rail passenger train service in a metropolitan or suburban area, including public authorities operating passenger train service.

This standard does not apply to:

1. Rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
2. Tourist, scenic, historic, or excursion operations, whether on or off the general railroad system of transportation;
3. Operation of private cars, including business/office cars and circus trains; or
4. Railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

ECP Passenger Cable-Based Braking System—Performance Requirements

1. Description of ECP braking system for passenger applications

An ECP brake system is a train-powered braking system actuated by compressed air and controlled by electronic signals originating from a lead locomotive or cab car. The electronic signals are used to communicate service and emergency brake applications, as well as to control power and receive feedback from other devices in the train. Since brake commands are derived from electronic signals, the brake pipe will typically remain charged and will provide backup brake commands.

The “cable-based” ECP brake system provides communications and a potential source of power to all the ECP brake devices in the train via a two-conductor electric trainline that spans the entire length of the train. The system provides shorter response times to braking commands and includes support for graduated releases and reapplications. The system responds appropriately to undesired separation or malfunction of hoses, cabling or brake pipe.

2. Functional and performance specification

This section describes the functional and performance requirements for an ECP brake system (which shall be designed for a minimum of 180 network devices spanning 12,000 ft), both in normal operation and in response to faults. The environmental conditions under which the system must operate are described in Section 3.

2.1 Primary functions

The brake system shall provide the following primary functions:

- graduated service brake applications and releases
- continuous reservoir charging
- configuration of braking level
- continuous fault detection and equipment status monitoring
- pneumatic backup
- passenger ECP operating mode
- passenger graduated and direct release emulation mode
- passenger ECP end-of-train (EOT) node functionality
- ECP emergency brake application

The system may include provisions for the following as requested by the railroad:

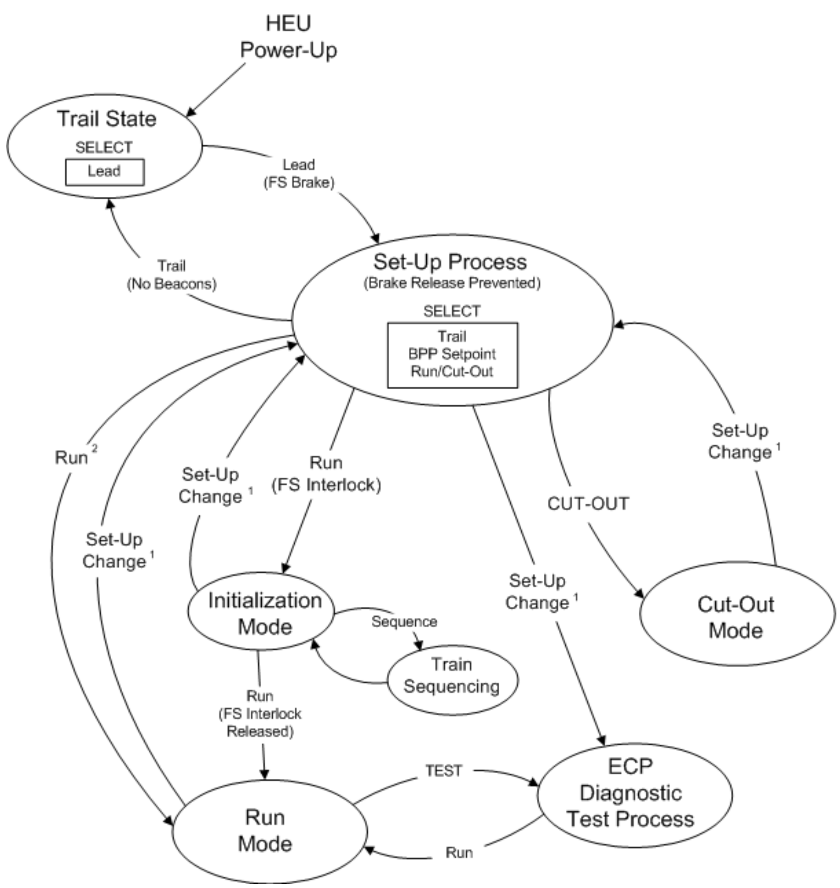
- interoperable snow braking control
- local load-weigh functionality

Section 2 is divided into five major areas; this first area (Section 2.1) is a list of primary functions. Section 2.2 covers system modes of operation, including pneumatic backup. Section 2.3 describes all normal operational functions performed by the system. Section 2.4 describes all the fault response functions of the system. Section 2.5 describes the functional features for mitigating cross-communications between two trains. The latter three areas describe in detail the functions and required performance of all major components and subsystems of the ECP brake system.

2.2 Operating modes

The passenger ECP system shall be defined by a passenger ECP mode of operation that is distinct from the freight mode of operation. When in passenger mode, several operating modes are defined, as illustrated in **Figure 1**. A particular set of procedures is followed and functions are performed in each mode. Three modes of operation are covered in this section: initialization mode (Section 2.2.3), RUN mode (Section 2.2.5) and CUTOUT mode (Section 2.2.6). An additional Section, 2.2.7 "All Modes," lists procedures and functional references that apply to all ECP brake system operating modes. Also described in this area are the power-up head end unit (HEU) lead/trail selection procedure (Section 2.2.1), setup operations (Section 2.2.2) and ECP brake system diagnostic tests (Section 2.2.4).

FIGURE 1
Passenger ECP System Operating Modes



Notes:
1. Setup changes are allowed only if the train is stopped or if a full-service brake application has been in effect for at least 60 s.
2. Transition to RUN mode without initialization is allowed only if the EOT beacon has not been lost for more than 15 s since the previous completion of initialization.

The HEU shall broadcast the current operating mode to all car control devices (CCDs) as part of the HEU beacon.

> **NOTE:** Throughout this standard, the term “locomotive” means either a locomotive or cab car performing the functions of a locomotive.

The passenger ECP system shall be capable of operating in emulation mode, as detailed in APTA PR-M-S-020-17, latest revision, Passenger Electronic 26C Emulation Braking System—Performance Requirements,” or equivalent performance of a conventional pneumatic system.

2.2.1 Head end unit lead/trail selection

2.2.1.1 Description of HEU trail

The HEU, when powered up, shall default to trail state. When in trail state, the HEU shall not broadcast any HEU beacons or system commands.

2.2.1.2 Selection of HEU lead

2.2.1.2.1 The engineer must select the HEU at the locomotive or cab car designated as “lead”; if any other HEU connected to the network has already been selected as lead, then this HEU shall not assume lead state until all other HEUs have been placed in trail state or trainline power is off and the engineer expressly confirms that lead operation should be allowed. Multiple lead HEUs in the network shall be handled as described in Section 2.4.11.

2.2.1.2.2 After lead selections are made and prior to completing the setup process, the lead HEU broadcasts HEU beacon messages containing a full-service (100 percent) TBC, a trainline power off command and initialization mode. Then the HEU continues the setup process.

2.2.2 Setup

Prior to entering passenger ECP operating mode, the system may require the operator to select the passenger lead cut-in mode of operation.

2.2.2.1 Description of setup

Setup is an operation that allows the engineer to change the ECP brake system configuration. With the exception of changing the trainline power mode, setup changes shall not occur unless the train is stopped or until a full-service application has been in effect for 60 s. Any setup change shall require an operator confirmation to become effective.

2.2.2.1.1 Entering Setup from trail state

Upon entering Setup from trail state, all ECP brake system configuration information and operating mode may be selected. Setup shall not be exited until all configuration information is confirmed or the HEU is placed in the trail state.

2.2.2.1.2 Entering Setup from RUN, Initialization, CUTOUT mode or diagnostic tests

Upon entering Setup from an operating mode, some or all ECP brake system configuration information and operating modes may be changed.

2.2.2.2 Setup operational procedures

In Setup, the following information may be entered.

2.2.2.2.1 HEU Trail

If trail state is selected, then no other information needs to be entered. The HEU enters trail state.

2.2.2.2.2 Trainline power mode selection

The engineer may select Automatic Power mode or Power Off mode at any time (see Section 2.3.3). The default is Power OFF.

2.2.2.2.3 Brake pipe pressure set point

The engineer must select the BP pressure set point (BP set point), or the engineer may accept the default setting. The BP pressure set point establishes the ECP brake system reference BP pressure. The minimum pressure setting for ECP brake systems shall be 70 psig and the maximum pressure setting shall be 110 psig, in increments of 1 psi.

2.2.2.2.4 Empty/load

Car loading is determined locally at the car or cab car (see Section 2.3.8, “CCDs determine car load value”).

2.2.2.2.5 Operating Mode Selection

The desired operating mode (RUN or CUTOUT) may be entered. If CUTOUT mode is selected, then the HEU shall release the brake application interlock and enter the desired mode. Transition to RUN mode without initialization is allowed only if the EOT beacon has not been lost for more than 15 s since the previous completion of initialization.

2.2.3 ECP brake system initialization (INIT mode)

After the operator has selected a lead locomotive or cab car and selected the required setup parameters, the system shall perform an initialization process per the requirements defined in this section. If ECP is already initialized, then the ECP system shall also allow the operator to reinitialize the system per the requirements defined in this section.

The ECP brake system must be initialized prior to entering RUN mode so that network devices and train conditions are registered. An EOT device is required to be connected for normal initialization of the train. When Initialization mode is entered, a full-service interlock is applied. The initialization sequence shall be performed by the HEU when RUN mode is selected by the engineer. Initialization involves establishing or confirming identity and position of all network devices in the trainline communication network. It also involves assigning a network address to each network device and downloading operational data, including vehicle weight and brake pipe pressure set point (see APTA PR-M-S-024-19, latest revision, “Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems.”) Specifically, the initialization procedure shall include the following:

1. Initial power-up to restart and cut in CCDs and EOT node. In order to initialize the ECP system, CCDs and EOT node shall be restarted via a trainline power application. The HEU shall prompt the engineer when entering Initialization to set trainline power to AUTO when safe to do so. Within 2 s after the trainline voltage has reached 100 VDC at the device, any CCDs or EOT node that were shut down restart (wake up) and begin to cut in. This procedure is necessary to prepare CCDs and EOT node for ECP brake system initialization. This 2 s power-up function shall not depend on the existence of EOT node or HEU beacons on the network. When the EOT node is activated, it shall begin transmitting EOT beacon and status messages to the HEU. The EOT node shall be activated by the presence of trainline power.
2. The HEU shall establish the version compatibility level of the train per APTA PR-M-S-024-19, latest revision, “Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems”.

3. The HEU shall poll the network to identify all network devices. When devices have been identified, they shall be assigned network addresses and shall be added to the HEU database.
4. The HEU database shall indicate the relative position of each network device within the train (correlated to reporting marks or road numbers). The relative position shall be determined as defined in Section 2.2.3.1.
5. If additional CCDs are added to the database, then the HEU shall configure the cars by downloading operational data to each additional CCD.
6. Car-specific data from the car ID module shall be retrieved from each CCD.
7. The HEU transmits train configuration data to all ECP trainline devices. This information includes the train net braking ratio and brake pipe pressure set point.
8. Each CCD determines its car loading value in order to adjust brake cylinder pressures to car loading (see Section 2.3.8, "CCDs determine car load value."
9. Locomotive-specific data from the locomotive ID module shall be retrieved from each trail HEU.
10. The HEU shall prompt the engineer to confirm or enter the total number of potentially operative brakes. When prompted to enter the total number of potentially operative brakes, the HEU shall allow the engineer to increase that number in increments of one operative brake. If a discrepancy is found, the database must be cross-checked against the actual train configuration. After confirmation of the number of potentially operative brakes in the train, the HEU shall begin the train sequencing process without requiring additional input from the operator. The HEU shall provide a means to cancel/abort train sequencing in process and still allow RUN mode to be entered.

During Initialization mode, the network devices shall not transmit exception messages except for critical loss exceptions, PSC exceptions and version compatibility exceptions per APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

The engineer may cancel the initialization procedure at any time. If the initialization procedure is canceled, then the HEU returns to the setup process and/or allows the engineer to restart the initialization process. When Initialization mode is exited, all fault logic shall be reset.

2.2.3.1 Sequencing

The ECP system shall provide the ability to sequence the train during ECP system initialization. The lead HEU, as part of the initialization procedure, shall determine the relative position and orientation of each vehicle within the train with respect to the locomotive on which the HEU designated as lead is installed.

2.2.3.1.1 General sequencing requirements

The following are general requirements for sequencing:

1. All network devices shall provide an indication of their capability to perform the sequencing process during initialization.
2. The system shall be able to determine the sequential order of the vehicles in the train with an accuracy of ±0 vehicles.
3. When sequencing is completed successfully, each vehicle shall retain its position and orientation.
4. Successful sequencing shall not be required for normal train operation.
5. Any failures related specifically to sequencing shall not affect normal train operation.
6. Sequencing shall not in any way inhibit the car's ability to maintain the requested train brake command as long as the CCD's battery has sufficient charge to operate the CCD.
7. Sequencing shall not be affected by a low battery on a CCD (one that can still power the CCD electronics but would normally cause the CCD to shut down to conserve the battery).

2.2.3.1.2 Locomotive equipment requirements for sequencing

The sequencing requirements for locomotive equipment are met by the trainline power supply and associated PSC, HEU and locomotive ID device.

2.2.3.1.2.1 Trainline power supply requirements for sequencing

The trainline power supply shall contain the hardware necessary to support train sequencing as defined in Section 2.2.3.1.4, “Hardware requirements for sequencing.”

2.2.3.1.2.2 Lead HEU requirements for sequencing

The HEU shall contain the software necessary to support train sequencing as defined in Section 2.2.3.1.5, “General software requirements for sequencing,” and Section 2.2.3.1.6, “Process steps for sequencing.”

2.2.3.1.2.3 Trailing locomotive requirements for sequencing

The HEU or the PSC on trailing locomotives shall contain the software necessary to support train sequencing as defined in Section 2.2.3.1.5, “General software requirements for sequencing,” and Section 2.2.3.1.6, “Process steps for sequencing.” If both the HEU and the PSC on a trailing locomotive indicates the capability to perform the sequencing process, the lead HEU shall select only one of the devices to perform the sequencing function for that vehicle.

2.2.3.1.2.4 Locomotive ID requirements for sequencing

The locomotive ID device shall contain the hardware and software necessary to support train sequencing as defined in Section 2.2.3.1.4, “Hardware requirements for sequencing,” Section 2.2.3.1.5, “General software requirements for sequencing,” and Section 2.2.3.1.6, “Process steps for sequencing.”

2.2.3.1.3 Car equipment requirements for sequencing

The sequencing requirements for rail car equipment are met by the CCD and car ID device.

2.2.3.1.3.1 CCD requirements for sequencing

The CCD shall contain the software necessary to support train sequencing as defined in Section 2.2.3.1.5, “General software requirements for sequencing,” and Section 2.2.3.1.6, “Process steps for sequencing.”

2.2.3.1.3.2 Car ID requirements for sequencing

The car ID device shall contain the hardware and software necessary to support train sequencing as defined in Section 2.2.3.1.4, “Hardware requirements for sequencing,” Section 2.2.3.1.5, “General software requirements for sequencing,” and Section 2.2.3.1.6, “Process steps for sequencing.”

2.2.3.1.4 Hardware requirements for sequencing

2.2.3.1.4.1 Trainline power supply requirements

The ECP trainline power supply shall provide a nominal 24 VDC output as defined in APTA PR-M-S-023-19, latest revision, “ECP Passenger Cable-Based Brake DC Power Supply—Performance Requirements.” This voltage shall be applied to the conductors of the trainline during the sequencing process.

2.2.3.1.4.2 Switchable load requirements

The ECP equipment on each car and locomotive shall provide a switchable load across the two conductors of the trainline. The switchable load, when activated, shall cause a DC current of 0.65 A ±0.1 A to flow between the load and the trainline power supply with the trainline voltage at 24 VDC. The total AC impedance presented by the ECP equipment on a vehicle shall be nominally 2000 ohms in the 100 to 450 KHz frequency band when the load is not activated and shall not be reduced below 500 ohms when the load is connected. The default state of the switchable load shall be not activated. With no switchable load connected and the trainline voltage less than 30 VDC, trainline current shall not exceed 0.17 mA per device.

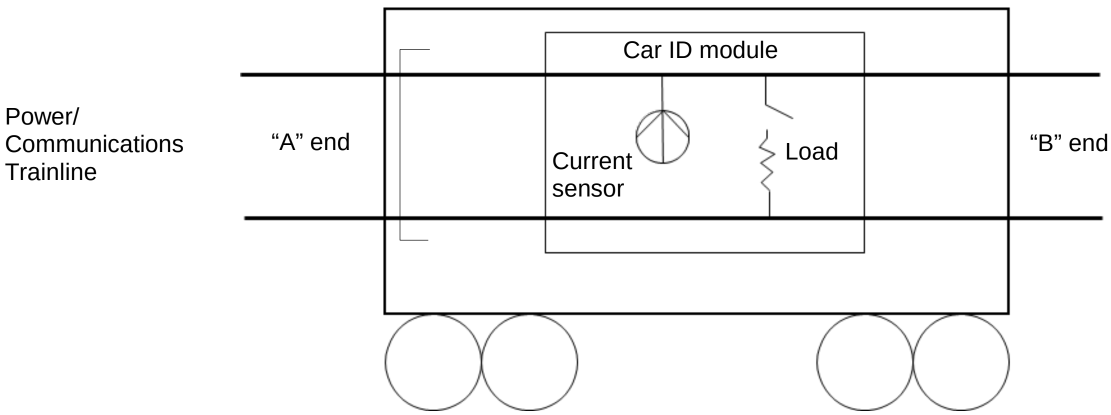
2.2.3.1.4.3 Current sensing requirements

The ECP equipment on each car and locomotive (rail vehicle) shall be capable of sensing the trainline current resulting from the activation of one switchable load as defined in Section 2.2.3.1.4.2, "Switchable load requirements," when that rail vehicle is between the trainline power supply and the activated switchable load. No current shall be sensed when the sensing vehicle is not between the trainline power supply and the activated switchable load. The ECP current sensor shall not be damaged by current up to 15 A.

2.2.3.1.4.4 Car hardware orientation

The default orientation of the current sensor and switchable load on each car relative to the A end and the B end shall be as shown in **Figure 2**. If the opposite orientation is used, then a parameter in the car ID shall be used to allow the CCD to invert the orientation data reported to the lead HEU.

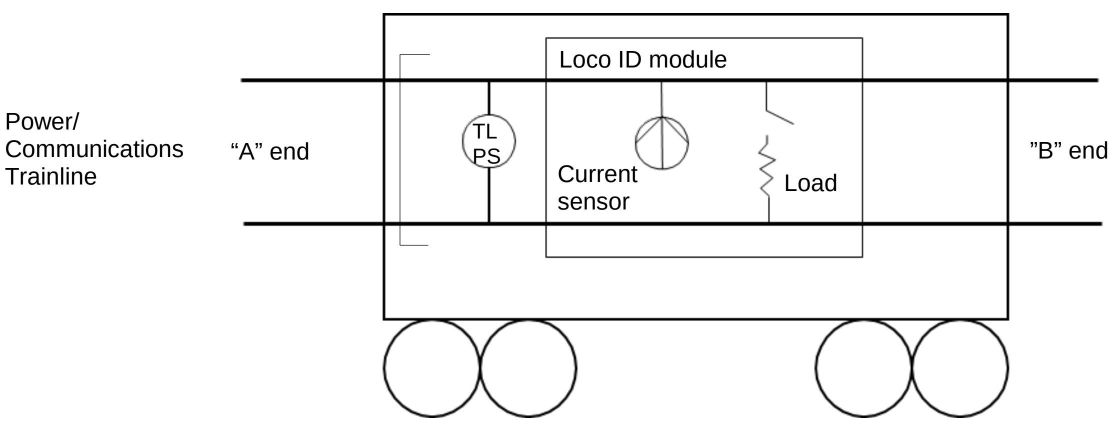
FIGURE 2
Car Orientation



2.2.3.1.4.5 Locomotive hardware orientation

The orientation of the current sensor, switchable load, and trainline power supply on each locomotive relative to the front (short-hood) and the rear (long-hood) shall be as shown in **Figure 3**. If the opposite orientation is used, then a parameter in the locomotive ID shall be used to allow the locomotive or cab car equipment to invert the orientation data reported to the lead HEU.

FIGURE 3
Locomotive or Cab Car Orientation



2.2.3.1.4.6 EOT node hardware requirements for sequencing

When the trainline voltage is less than 30 VDC, the current drawn from the trainline by the EOT node shall not exceed 0.17 mA.

2.2.3.1.5 General software requirements for sequencing

The CCD/car ID, HEU/locomotive ID, and optionally the PSC/locomotive ID shall provide the following functions to support sequencing:

1. Connect load across the trainline in response to lead HEU commands.
2. Provide a timing function to automatically disconnect the load after trainline current has reached and maintained a level as specified in Section 2.2.3.1.4.2, "Switchable load requirements," for a minimum of 200 ms and a maximum of 300 ms of continuous connection.
3. Detect a valid sequencing trainline current pulse when sequencing is active. A valid current pulse shall be detected if trainline current is at or above the limit as specified in Section 2.2.3.1.4.2, "Switchable load requirements," for a minimum of 100 ms and a maximum of 400 ms continuous.
4. Maintain a lead locomotive sense status that is initialized to false and set to true if a valid sequencing trainline current pulse is detected during the lead locomotive sense phase.
5. Maintain a pulse counter that is initialized to zero and incremented by one during the sequencing phase each time a valid trainline current pulse is detected when this vehicle is not the one connecting its load.
6. Maintain a vehicle orientation status relative to the lead locomotive or lead cab cab that is determined by detecting the presence/absence of trainline current when this vehicle's load is connected, comparing it to a car/locomotive ID parameter that identifies how the current sensor was installed on the vehicle, and reversing it if the lead locomotive sense status is set to true.
7. Determine the vehicle position based on the total number of vehicles sequenced, pulse count and lead locomotive sense status. If the lead locomotive sense status is set to true, the vehicle position shall be calculated as pulse count +1; otherwise the vehicle position shall be calculated as number of vehicles sequenced − pulse count.
8. Report the sequencing results as defined in APTA PR-M-S-023-19, latest revision, "ECP Passenger Cable-Based Brake DC Power Supply—Performance Requirements," to the lead HEU when requested.

2.2.3.1.6 Process steps for sequencing

The lead HEU shall control the sequencing process via network commands to a PSC, trailing locomotives and all cars. Prior to beginning the sequencing process, the HEU must have completed the process of identifying all network devices in the train and assigning them unique network addresses. The general process involves a preparation phase, a lead locomotive sense phase if necessary, a vehicle sequencing phase and a data collection phase.

2.2.3.1.6.1 Sequencing preparation phase

The preparation phase is used to initialize devices for sequencing. The lead HEU shall use the following steps during this phase:

1. The HEU shall broadcast a Prepare for Sequencing command on the trainline to initialize all participating devices for sequencing. In response to this command, the CCDs and EOT node disable their normal low-battery shutdown logic and participating devices reset their position count and orientation status to unknown and lead locomotive sense status to false.

2. The HEU shall command 230 VDC trainline power to off.
3. If trainline voltage is not less than 10 VDC after 30 s, then the system shall provide an operator indication/warning that sequencing is not available and shall abort the sequencing process. After verifying that trainline voltage is less than 10 VDC, the HEU shall command the lead PSC to energize 24 VDC trainline power.
4. After a minimum of 5 s, the HEU shall verify that 24 VDC is present on the trainline.
5. After verifying that 24 VDC is present on the trainline, if the enabled PSC is on the lead locomotive, then the HEU shall begin the vehicle sequencing phase; otherwise it shall begin the lead locomotive sense phase.

2.2.3.1.6.2 Preparation phase message summary

1.	HEU → All Vehicles	Prepare for Sequencing
2.	HEU → All PSCs	Deactivate 230 VDC
3.	HEU → One PSC	Activate 24 VDC

2.2.3.1.6.3 Lead locomotive sense phase

This phase is required if a non-lead locomotive trainline power supply and associated PSC are used for providing the trainline voltage for sequencing. The lead HEU shall use the following steps during this phase:

1. The HEU shall broadcast an Enable Lead Sense command on the trainline to enable the lead sense function on all participating devices.
2. The HEU commands the load on the lead locomotive to be connected across the trainline.
3. The load on the lead locomotive shall be connected and removed as defined in Section 2.2.3.1.5, “General software requirements for sequencing.”
4. All participating trailing devices shall read their current sensor and update their lead locomotive sense status as defined in Section 2.2.3.1.5, “General software requirements for sequencing.”
5. Steps 2 through 4 may be repeated up to two times to minimize the possibility of errors.

2.2.3.1.6.4 Vehicle sequencing phase

During this phase, each car and locomotive determines its relative position and orientation. The lead HEU shall use the following steps during this phase:

1. The HEU commands all participating devices to start counting current pulses.
2. The HEU commands a trailing device to connect its load across the trainline.
3. The load on the trailing device shall be connected and removed as defined in Section 2.2.3.1.5, “General software requirements for sequencing.” The associated network device shall respond with a Load Connected message.
4. All trailing devices participating in sequencing shall read their current sensor and update their sequencing information as defined in Section 2.2.3.1.5, “General software requirements for sequencing.”
5. A minimum of 50 ms and a maximum of 150 ms after the load has been disconnected, the device shall send a Load Removed message to the HEU.
6. The HEU waits a minimum of 50 ms.
7. The HEU repeats steps 2 through 6 for each vehicle in the train database.
8. The HEU commands all trainline devices to stop counting pulses.

2.2.3.1.6.5 Vehicle sequencing phase message summary

1. HEU → All Vehicles Start Pulse Count
2. For each Vehicle(i) where (i = 1,# of vehicles in train database):
    a. HEU → Vehicle(i) Connect Load
    b. HEU ← Vehicle(i) Load Connected c. HEU ← Vehicle(i) Load Removed
3. HEU → All Vehicles Stop Pulse Count

2.2.3.1.6.6 Data collection phase

The last phase is where each car and locomotive reports its sequencing results to the lead HEU. The HEU shall use the following steps during this phase:

1. The HEU shall query each vehicle for its position count, orientation and other sequencing information as defined in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."
2. After all vehicles have been queried for their sequencing results, the HEU shall broadcast an End Sequencing command to all trainline devices. In response to this command, the CCDs and EOT node enable their normal low-battery shutdown logic.
3. After sequencing is complete, the HEU can resume normal control of trainline power.

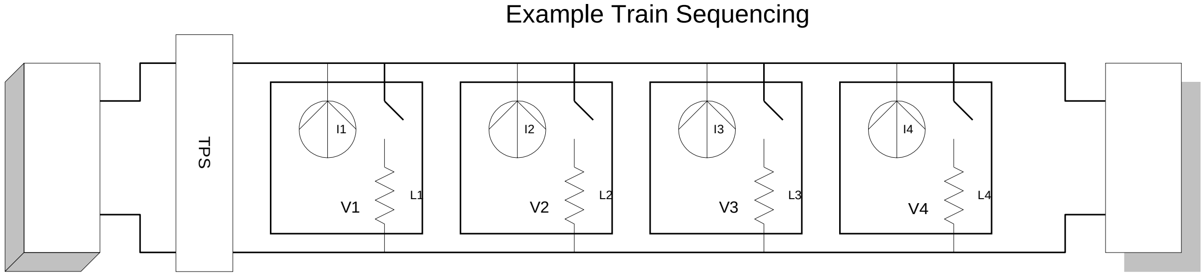
NOTE: The lead HEU may, at the option of its manufacturer, resume normal control of trainline power prior to sending the queries to each vehicle for its sequencing data.

2.2.3.1.6.7 Data collection phase message summary

1. For each Vehicle(i) where (i = 1,# of vehicles in train database):
    a. HEU → Vehicle(i) Query Sequencing Results
    b. HEU ← Vehicle(i) Position Count and Orientation HEU → All Vehicles Start Pulse Count
2. HEU → All Vehicles End Sequencing
3. HEU → PSC Turn Off 24 VDC
4. HEU→ Any PSC Activate 230 VDC

NOTE: The lead HEU may, at the option of its manufacturer, resume normal control of trainline power prior to sending the queries to each vehicle for its sequencing data.

FIGURE 4
Example Train Sequencing



Consider a sample train consist as shown electrically in **Figure 4**. This train has four vehicles. The HEU performs four iterations during the vehicle sequencing phase. During each iteration, only one vehicle connects a load across the trainline. All vehicles detect the presence or absence of current and keep count of the number of times current was detected. This information is stored in Pulse Count at each vehicle. The vehicle's actual position is based on the value of Pulse Count and the total number of vehicles in the train consist.

TABLE 1
Train Sequencing Example

Load Connected/ Iteration	I1/V1	I2/V2	I3/V3	I4/V4
L4	present(1)	present(1)	present(1)	Note 1
L3	present(1)	present(1)	Note 1	absent(0)
L2	present(1)	Note 1	absent(0)	absent(0)
L1	Note 1	absent(0)	absent(0)	absent(0)
Pulse Count	3	2	1	0
Position (#Vehicles–Count)	1	2	3	4

Note 1: Vehicle that connected its load does not update its pulse count.

2.2.3.2 Completion of initialization mode

Before the full-service interlock is allowed to clear, the HEU shall attempt to query the status of all CCDs. If the HEU detects, based on status information, that a CCD has a problem, then the HEU shall warn the engineer, and the engineer may cut out the CCD. To clear the full-service interlock and operate in RUN mode, the engineer's brake controller must be in the full-service position.

2.2.3.3 Operable brakes

Locomotives and cars (including cab cars) shall be included in the percent operable brake calculation.

Each locomotive axle, on locomotives weighing more than 200,000 lbs, shall count as two car axles in the percent operable calculation.

Or

For locomotives that are capable of meeting the passenger car braking requirements, each locomotive axle shall be counted as one axle only.

ECP for passenger-equipped vehicles may support cutout brake detection to the level of operator intervention.

> **NOTE:** Passenger vehicles typically allow for the isolation of each truck.

The lead head end unit (HEU) shall account for such fractional degradations in its percent operable calculation.

2.2.4 System diagnostics and testing

The passenger ECP system shall successfully pass all applicable tests defined in the APTA PR-M-S-005-98, Rev. 4, Code of Tests for Passenger Car Equipment Using Single Car Testing Device.

NOTE: For ECP equipment, the manufacturer procedure must be available at the location where single car testing is performed.

An ECP braking system diagnostic test may be requested by the engineer interacting with the HEU. Functions of the ECP braking system diagnostic test include the following.

2.2.4.1 Trainline power supply tests

2.2.4.1.1 This test shall be available during RUN mode while the train is stopped, trainline power is on, and at least a full-service brake application is being commanded by the HEU. Activation of trainline power during this test shall be in accordance with Section 2.3.3.1.2. To complete this test, EOT beacons and head end termination must be continuously present.

This test shall verify the following:

- That each trainline power supply in the train can be activated as a primary power supply for providing 230 VDC trainline power (see Section 2.3.3.2.1 and Section 2.3.3.3.2.1).
- That each trainline power supply in the train can be activated as a secondary power supply for providing 230 VDC trainline power (see Section 2.3.3.2.2).
- That all available trainline power supplies can be activated together to provide 230 VDC trainline power continuously throughout the train.
- That the lead trainline power supply can provide 24 VDC for sequencing. To perform the Trainline Power Supply test, the HEU shall do the following:
    1. Command trainline power off.
    2. Command the CCDs to low-power mode.
    3. Command 230 VDC trainline power on.
    4. Enable a single trainline power supply as primary.
    5. Enable the other trainline power supplies as secondaries.
    6. Wait at least 15 s for the trainline voltage/current to stabilize.
    7. Command the CCDs to normal power mode.
    8. Verify that trainline voltage at each trainline supply is at least 210 VDC.
    9. Verify that trainline voltage at the EOT node is at least 100 VDC.
    10. Repeat steps 1 through 9 for each trainline power supply in the train.
    11. Command trainline power off.
    12. Enable the lead trainline power supply to provide 24 VDC.
    13. Verify that trainline voltage at the EOT node is at least 20 VDC and less than 30 VDC.
    14. Command 230 VDC trainline power on.

2.2.4.1.2 At the conclusion of the Trainline Power Supply test, the following information shall be made available to the operator:

- Number of trainline power supplies tested
- Any trainline power problems detected
- Any problem with the lead power supply providing 24 VDC

2.2.4.2 CCD/EOT node battery tests

When operating in passenger ECP mode, the battery diagnostic test is not required to be supported by the car control devices (CCDs) and may be misleading due to the presence of the local car battery power source.

The purpose of this test is to identify any CCDs or EOT node with batteries that are low on charge, are missing or need replacing. This test shall be available during RUN mode while the train is stopped and at least a full-service brake application is being commanded by the HEU. Activation of trainline power during this test shall be in accordance with Section 2.3.3.1.2.

To perform the CCD/EOT node battery test, the HEU shall do the following:

1. Ensure that trainline power is on continuously for 30 min.
2. Query each CCD for status while trainline power is on.
3. Command trainline power off.
4. After trainline power has been off for 60 s, query each CCD for status.
5. Command trainline power back on.

At the conclusion of the CCD/EOT node battery test, the HEU shall provide the following information to the operator:

- Number of CCDs tested
- Car reporting mark of any CCDs with a potential bad or missing battery (CCDs that responded to the HEU query while trainline power was on in step 2 of the test but did not respond to the HEU query when trainline power was off in step 4)
- Car reporting mark of any CCDs reporting a low battery condition with trainline power off
- EOT node battery status

2.2.4.3 Train Snapshot

The Train Snapshot is a diagnostic feature that is intended to provide the engineer and maintenance personnel with a snapshot of the current ECP status of the train. The Train Snapshot function shall be available during RUN mode while the train is stopped and at least a full-service brake application is being commanded by the HEU. The Train Snapshot may be performed with trainline power either ON or OFF.

The Train Snapshot function shall determine and make available to the operator the following information:

1. The number of ECP-equipped locomotives in the train that are communicating with the HEU
2. The number of ECP trainline power supplies in the train that are communicating with the HEU
3. The number of CCDs in the train that are communicating with the HEU
4. The number of CCDs reporting trainline power ON
5. The number of CCDs counting as Inoperative
6. The number of CCDs reporting brake pipe pressure below the Loss of BP exception threshold as defined in Section 2.4.3.3
7. The number of CCDs reporting reservoir pressure below the Low Reservoir exception threshold as defined in Section 2.4.6
8. The number of CCDs reporting battery charged at or below the Low Battery exception threshold as defined in Section 2.4.8
9. The EOT device as one of EOT, LOCO, PLUG or NONE based on the following:
    - EOT if a standalone end-of-train device is present
    - LOCO if a locomotive is acting as an EOT device
    - PLUG if a trainline termination plug is sending EOT beacons
    - NONE if no EOT beacons are detected
10. The status of the EOT as one of BATT OK or LOW BATT based on the following:
    - BATT OK if the EOT device is reporting battery not low
    - LOW BATT if the EOT device is reporting a low battery

Example scenario:

Actual Train Configuration #1

- Three ECP-equipped locomotives (one HEU and one TPS per locomotive)
- 100 ECP-equipped car singles (1 CCD per car)
- EOT device

Train Snapshot report to the engineer:

TRAIN SUMMARY:	
# of ECP Locomotives Reporting	3
# of ECP Trainline Power Supplies	3
# of CCDs Reporting	100
# of CCDs Reporting Trainline Power ON	100
# of Inoperative CCDs	0
# of CCDs Reporting Brake Pipe Pressure Low	0
# of CCDs Reporting Reservoir Pressure Low	0
# of CCDs Reporting Battery Low	0
EOT Device	EOT
EOT Status	BATT OK

2.2.5 RUN mode

2.2.5.1 Description

RUN mode is the main mode of operation of the ECP brake system and is selected when the train consist is fully configured and ready for normal road operations. As such, all fault detection modes are enabled to permit safe operation of trains at full speed.

2.2.5.2 Normal operational procedures

The following describes the normal sequence of operation in RUN mode. Section 2.2.5.3, "Fault detection and response procedures," describes fault detection and response operations.

2.2.5.2.1 Run mode brake control

RUN mode brake control provides the full functionality of the ECP brake system for road operations. The RUN mode brake control includes the following:

NOTE: The passenger ECP EOT node may not report the BP.

1. The engineer's brake command is read from the human-machine interface, translated by the HEU to train brake commands (TBCs), and broadcast to all network devices as part of the HEU beacon message.
2. HEU shall broadcast a "configuration" message containing BP set point, and other information (reference APTA PR-M-S-024-19, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems,"), as follows:
   - every time "setup" is changed
   - once every 120 s
3. If an emergency command (TBC = 120 percent) is made, then a 60 s emergency interlock timer is started.

4. If an emergency command is in effect, the HEU shall not release it until the 60 s interlock has expired. If the emergency brake application is in response to a fault condition, then it shall additionally be maintained until the fault condition is removed or cleared or the operating mode changed.
5. If a release from emergency is requested, the engineer must place the control to the full-service position. Once the emergency interlock has expired, release from emergency shall be enabled unless a fault condition still exists. Release from emergency shall go directly to full service.
6. If a full or partial release from the current brake application is selected, the TBC transmitted shall reflect the control input unless a penalty brake application, an emergency or a full-service interlock is active.
7. HEU train brake commands are expressed as a percentage of full-service braking force (10 percent [minimum service], 100 percent [full service], in increments of 1 percent), plus 0 percent for full release and 120 percent for emergency. They are transmitted by the HEU once per second as part of the priority HEU beacon message. An emergency brake command shall be transmitted immediately when required and repeated once per second thereafter.
8. The HEU beacon is broadcast and includes the current operating mode, TBC, trainline power on/off, and network device status query (Section 2.3.17.1.2). Other HEU commands or information may be transmitted as well. See Section 2.3.17.8, “Control messages.”
9. A CCD may automatically cut out/in under the conditions described in Section 2.3.12.
10. CCD BCP control: CCDs use their preprogrammed braking constant C (and other parameters that may be required) with the accepted load data to give the proper BCP in response to each TBC. See Section 2.3.4 through Section 2.3.11 for performance requirements of BCP response.
11. EOT node transmits beacon to HEU: The EOT node status beacon shall be transmitted to the HEU once per second and may include BP, percentage of full battery charge and other data. See Section 2.3.17.4, “EOT beacon/status message.”

2.2.5.3 Fault detection and response procedures

The following describes the sequence of operation for detecting and responding to various component and system faults in RUN mode:

2.2.5.3.1 General fault classification

2.2.5.3.1.1 Faults are categorized according to type and severity of fault and according to which major component is responsible for its detection and handling.

2.2.5.3.1.2 General fault types are outlined in Section 2.2.5.3.1.3 in order of severity. They comprise three basic classes of faults:

- The first class of faults is the most severe and includes those faults that are likely to jeopardize safety. These faults must result in an immediate automatic emergency brake application.
- The second class of faults is somewhat less severe and must result in an immediate automatic full service (or penalty brake application).
- The least severe fault class must result in a warning to the engineer, but must not significantly interfere with the normal operation of the brake system.

2.2.5.3.1.3 Note that some faults are compound faults (meaning a coincidence of two or more faults).

- **Automatic emergency:**
  - Critical system loss (loss of BP or communication)
- **Automatic full service:**
  - Less than 50 percent operative brakes, causes for which include low battery charge, low reservoir charge, CCD shutdown, CCD cutout and other disabling faults
  - Low EOT battery charge
  - Low EOT BP
  - Multiple lead (active) HEUs
- **Warning only:**
  - Low trainline voltage
  - High trainline voltage
  - Incorrect BCP
  - Percentage of operative brakes falls below 85 and 75 percent

NOTE: In the passenger ECP application, the cars may have access to the local car battery and will be able to maintain functionality without trainline power via available local car battery.

NOTE: It is expected that brake pipe (BP) may not consistently remain charged in ECP. As a result, the ECP system shall not generate faults should a brake pipe service reduction be detected.

NOTE: In the passenger operating mode, the system will not enforce an ECP penalty application if a pneumatic brake application is commanded by the electronic air brake (EAB).

2.2.5.3.2 HEU fault detection, response and recovery

The HEU shall perform fault detection and response procedures as described in Section 2.4.

2.2.5.3.3 CCD Fault detection and response

CCDs shall perform fault detection and response procedures as described in Section 2.4.

2.2.5.3.4 EOT Node fault detection and response

The EOT node shall perform fault detection and response procedures as described in Section 2.4.

2.2.5.3.5 PSC Fault detection and response

The PSC shall perform fault detection and response procedures as described in Section 2.4.

2.2.5.4 Trainline termination plug

The purpose of the trainline termination plug is to allow maintenance and fault isolation with trainline power on continuously without an ECP EOT node being present. A trainline termination plug may be used in place of an ECP EOT node to allow trainline power to remain on continuously. Train movement in RUN mode with a trainline termination plug shall not be allowed and is accomplished by not allowing the train brake to be released based on the HEU detecting EOT node low battery charge (Section 2.4.10.4).

2.2.5.4.1 The requirements of the trainline termination plug are as follows:

- It shall not have a battery.
- It shall not have a marking device/light.
- It shall not detect motion.
- It shall not connect to the brake pipe.
- It shall read trainline voltage.

- Within 2 s of the trainline voltage reaching 100 VDC, the trainline termination plug shall activate and begin sending the EOT beacon.
- The trainline termination plug shall deactivate when trainline power transitions below 100 VDC.
- The trainline termination plug shall draw less than 0.17 mA when trainline voltage is 30 V and below.
- A trainline termination circuit shall be provided.
- The EOT beacon sent by the trainline termination plug shall include the following:
  - Brake pipe pressure of 254 psi
  - Marking device/light of Unknown
  - Motion detected of Unknown
  - Battery charge of 0 percent
  - Battery status of Not Charged
  - Trainline voltage

2.2.6 CUTOUT mode

The HEU shall wait until the brake pipe has dropped below 25 psi at the HEU before indicating CUTOUT mode in the HEU beacon.

> **NOTE:** As CCDs will revert to emulation when ECP ends, this requirement will prevent the failure mode of releasing brakes if ECP is ended and BP is charged.

2.2.7 All modes

2.2.7.1 Description

This section lists functions and features that must be present in all ECP brake system modes of operation when applicable. Refer to Section 2.3 for detailed functional descriptions.

2.2.7.2 Functions and features applicable to all modes of operation

1. HEU cab displays and controls (engineer interface) include the following:
   - Normal displays (see Section 2.3.1.1)
   - Warnings and indications (see Section 2.3.1.2)
   - Engineer controls (see Section 2.3.1.3)
2. Manual brake cylinder and reservoir venting
3. Pneumatic backup (see Section 2.3.18)
4. Multiple lead HEUs on the network (see Section 2.4.11)
5. A CCD shall be activated by presence of trainline power
6. An EOT node shall be activated by the presence of trainline power
7. Continuous reservoir charging (see Section 2.3.19)

> **NOTE:** In addition to trainline power, the brake system on the car may have access to the local car battery/power system and will remain activated in the absence of trainline power. The EOT node may also have access to the local car battery/power.

2.2.8 Passenger emulation mode

Passenger emulation mode allows an ECP-equipped car to perform like a standard pneumatic car. This section defines the requirements for transitioning between ECP and emulation mode for ECP cars.

2.2.8.1 Entering passenger emulation

1. **Entering passenger emulation from power-up:** Upon power-up, if the CCD has not established a connection to a lead HEU per Section 2.5.1.2, then the CCD shall enter emulation mode within 10 s.

2. **Entering passenger emulation when ECP is CUTOUT:** When the CCD receives HEU beacons from the connected lead HEU indicating CUTOUT mode, the CCD shall enter emulation mode and default to the brake pipe pressure set point indicated in the last train dynamic config message received when in ECP mode.
3. **Entering passenger emulation on critical loss:** The CCD shall stop responding to HEU commands and enter emulation mode when it has detected a loss of HEU and the brake pipe pressure is below 25 psi. The CCD shall default to the brake pipe pressure set point indicated in the last train dynamic config message received when in ECP mode. If the brake pipe does not drop below 25 psi, then the vehicle shall maintain the last ECP brake application.

2.2.8.2 Entering ECP operation

A CCD shall enter ECP operation when a connection to a lead HEU has been established per Section 2.5.1.2.

2.2.8.3 Emulation performance

When operating in emulation mode, the passenger cars shall make brake applications based on changes in brake pipe pressure. The car shall support both graduated and direct release. The emulation performance is defined in APTA PR-M-S-020-17, Passenger Electronic 26C Emulation Braking System – Performance Requirements".

When operating in emulation mode, the CCD shall be capable of responding to the snow brake command from the locomotive if the car is so equipped.

2.3 Normal operating functions

2.3.1 Cab displays and controls

The ECP brake system engineer interface (controls, displays and alarms) may be provided directly by the HEU or via the locomotive system integration interface, and shall include the features and functions described in this section.

2.3.1.1 Normal displays

Information normally displayed in the lead locomotive shall include the following:

1. Percentage brake command (current TBC)
2. Current EOT BP (if provided and valid in EOT beacon), updated once per second
    a. If the EOT beacon's brake pipe pressure is 254 psi, then the EOT BP will be displayed as TTP. This is an indication that a trainline termination plug (Section 2.2.5.4) is sending the EOT beacon.
3. Percentage operating brakes
4. Trainline power status to include the following:
    a. Trainline power command/status (ON, OFF, AUTO or 24 V)
    b. If an EOT node is present, then the ECP display shall provide an indication that trainline power is ON/OFF at the EOT node.
    c. The ECP display shall provide an indication if trainline power is not continuous throughout the train.
5. Total potentially operative brakes
6. At least the following car status data for any car requested (Section 2.3.17.3):
    a. CCD cut-in/cut-out status
    b. Brake pipe pressure
    c. Reservoir pressure
    d. Brake cylinder pressure

   e. Percentage of car load
   f. Battery percentage charged
   g. Trainline power status
   h. Empty/load device type (None Installed, Mechanical Device, Electronic Device)
7. Operating mode
8. Train brake effort (TBE): An average of the train's car braking effort as reported by each CCD shall be displayed during RUN mode (Section 2.3.18.3.1).

2.3.1.2 Warnings and indications

Warnings are generally not required when an individual CCD has malfunctioned or ceases operation. Warnings and indications shall include the following:

1. Warn of absence of EOT beacon (Section 2.4.2.1).
2. Warn of low battery charge on EOT node (Section 2.4.8.4).
3. Warn of less than 95 percent, 90 percent, 85 percent, 75 percent and 50 percent operative brakes in train (Section 2.4.5). This is an acknowledged warning.
4. Warn of low trainline voltage (Section 2.4.7). This is an acknowledged warning.
5. Warn of critical loss reported by two or more network devices (Section 2.4.4).
6. Warn of HEU shutdown resulting from uncontrolled signal transmissions from a transceiver (Section 2.4.2.7).
7. Warn of multiple lead (active) HEUs in the network (Section 2.4.11).
8. Warn of presence of more than 30 VDC on the trainline when power is off. This is an acknowledged warning (Section 2.4.9).
9. Warn of CCD with incorrect BCP. This is an acknowledged warning (Section 2.4.10.2).

2.3.1.3 Engineer controls

2.3.1.3.1 HEU brake control shall provide the following brake commands and functions. Each function must be available or accessible in one operator motion from any other function.

- Minimum service (10 percent application)
- Full service (100 percent application)
- Emergency (120 percent application)
- Full release (0 percent application)
- Graduated applications and releases in 1 percent increments between 10 percent and 100 percent (full-service) application.
- Suppression (when applicable)
- Acknowledgement (when applicable)

2.3.1.3.2 Means of implementation of other required inputs shall be manufacturer-specific.

2.3.1.4 Interaction with locomotive systems/signals

> **NOTE:** In the event of a safety system penalty, BP may reduce to or beyond a fail-safe application.

The HEU should be capable of responding to or generating the following locomotive system signals:

1. Alerter (see Section 2.3.1.4.1)
2. PCS/PCR (see Section 2.3.1.4.2)
3. Cab signal/overspeed (see Section 2.3.1.4.3)
4. Suppression (see Section 2.3.1.4.3)

2.3.1.4.1 Alerter (safety control magnet valve)

The HEU shall be capable of detecting a conventional penalty brake application initiated from the safety control magnet valve or similar device if the locomotive is so equipped. On detection of a penalty brake application from this device, the HEU shall increase the current electronic brake application to at least 100 percent brake command for as long as the penalty remains in effect.

2.3.1.4.2 PCS/PCR

The HEU shall be capable of sending the locomotive a signal that will unload the engine. This signal shall be asserted on any electronic emergency and ECP braking automatic electronic penalty application, which includes the system fault-initiated brake applications listed in Section 2.4.1, and shall remain asserted until the application has been released.

2.3.1.4.3 Cab signal/overspeed

The HEU shall be capable of detecting brake applications initiated by the train control system such as positive train control (PTC) and cab signal/overspeed systems. The HEU may treat PTC-initiated applications as a cab signal/overspeed application per this section.

2.3.1.4.3.1 The HEU shall be capable of detecting a conventional penalty brake application initiated from the cab signal magnet valve or similar device if the locomotive is so equipped. On detection of a penalty brake application from this device, the HEU shall increase the current electronic brake application to at least 100 percent brake command for as long as the penalty remains in effect.

2.3.1.4.3.2 In addition, the HEU shall provide a means of providing to the locomotive cab signal equipment (if the locomotive is so equipped) a signal indicating that an electronic suppression application has been made by the engineer.

2.3.1.4.3.3 The suppression signal to the cab signal equipment shall be a fault-tolerant system, since a false suppression signal from the HEU will render the cab signal system unable to stop the train in the event of a fault.

2.3.1.4.3.4 The train brake command shall be independently monitored to ensure that cab signal penalties are properly enforced in the event of a failure and that a pneumatic emergency, ECP emergency or penalty application is independently commanded.

2.3.1.5 Locomotive retardation during ECP braking

The passenger ECP system shall support locomotive braking in response to ECP commands.

2.3.1.5.1 The requirements for locomotive retardation during ECP braking shall be railroad-specific in that not all railroads may want automatic locomotive brake cylinder pressure control or dynamic braking during ECP brake applications (e.g., railroads that always bail off automatic brake applications). The requirement to provide the ability to have locomotive retardation during ECP brake applications shall not preclude manufacturers and railroads from developing other braking systems that meet the intent of providing appropriate locomotive retardation in conjunction with ECP train braking as long as these systems allow for interoperability among locomotives equipped with different manufacturers' ECP equipment.

2.3.1.5.2 The requirements for control of locomotive retardation during ECP braking will normally apply to the ECP equipment on the lead locomotive and to the controlling locomotive in a remote, distributed power locomotive consist. All other locomotives normally will be controlled via existing locomotive multiple-unit (MU) cables and pipes.

2.3.2 Communication network test

Testing of network communication integrity may be performed during RUN mode and at other times at the discretion of the manufacturer. The test may include evaluation of error rates and/or analysis of signal attenuation through the network.

2.3.2.1 To aid in system diagnostics, CCDs, PSCs and EOT nodes shall maintain a count of CRC errors detected by the communication network controller. This count shall be reset to zero at power-up and once per hour by the HEU. Each CCD/PSC/EOT node shall set a flag in its status report if the CRC error count exceeds a threshold broadcast by the HEU. The HEU may use this information to identify malfunctioning network devices or groups of network devices.

2.3.2.2 To aid in system diagnostic services, the HEU may provide a means to measure the communication signal voltage level at its interface to the communication medium. If provided, the HEU shall make this measurement with a relative resolution of ±0.5 dB over a minimum 50 dB dynamic range. The hardware that provides this measurement shall have no adverse effect on the communication signal. Determination of trainline faults shall be manufacturer-specific. A special “quiet” state shall be available when the train is stopped and holding a full-service interlock, as defined in APTA PR-M-S-024-19, latest revision, “Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems.”

2.3.3 Trainline power control

Trainline power shall be controlled by the HEU via commands to the PSCs and a power control flag in the HEU beacon. The HEU power control shall be derived from a combination of engineer input and other mode and fault data as defined in this section.

2.3.3.1 Trainline power mode control

The engineer shall be permitted to select the trainline power mode at any time. There shall be two engineer-selectable trainline power modes: OFF and AUTOMATIC. The default trainline power mode shall be OFF. The HEU may change the trainline power mode from AUTOMATIC to OFF as defined in Section 2.3.3.1.2.

2.3.3.1.1 Power OFF mode

When the power OFF mode is selected or entered automatically, the HEU shall disable all power supplies in the train by setting the power control flag in the HEU beacon to the OFF state. All PSCs shall disable their associated trainline power outputs when the power control flag in the HEU beacon is set to OFF.

2.3.3.1.2 AUTOMATIC power mode

When AUTOMATIC power mode has been selected, the action performed by the HEU shall be as defined below:

1. When transitioning from OFF to AUTOMATIC mode:
    a. The HEU shall provide a warning indicating that trainline power will be applied.
    b. After the engineer has acknowledged the warning, the HEU shall request a confirmation that all personnel are clear from the trainline.
    c. After receiving this confirmation, the HEU shall command trainline power to be activated. If the head end termination and EOT node are not detected within 8 s after trainline voltage has exceeded 30 VDC at the activated PSC, the HEU shall automatically command that power be disabled.

2. If the head end termination is present and the HEU has received one or more EOT beacons in the last 6 s, it shall command that trainline power be on continuously until one or more of the following occurs:
   - A loss of EOT node is detected
   - A loss of head end termination is detected
   - A disabling trainline power fault is detected
   - The engineer commands trainline power OFF
   - The HEU commands trainline power OFF during diagnostic tests
3. If trainline power is commanded to OFF by the engineer, reactivation of trainline power shall require the engineer to command the trainline power mode to AUTOMATIC.
4. If trainline power is shut down due to a loss of EOT node communications, loss of head end termination or disabling fault condition, then the trainline power mode shall continue to be AUTOMATIC with trainline power commanded to OFF. While the trainline power mode is AUTOMATIC, trainline power may be re-enabled by the HEU without operator intervention. Note that there are fault conditions that would not allow power to be automatically re-enabled and turned ON. While in AUTOMATIC mode, if a loss of EOT node communications or loss of head end termination is detected for more than 30 s, then trainline power control shall revert to the Power OFF mode, and reactivation of trainline power shall require the engineer to command the trainline power mode to AUTOMATIC.

2.3.3.2 Trainline power supply controller (PSC) interface to HEU

The PSC shall provide a control and status interface to the HEU via the trainline in accordance with the requirements of APTA PR-M-S-023-19, latest revision, “ECP Passenger Cable-Based Brake DC Power Supply—Performance Requirements,” latest revision, and APTA PR-M-S-024-19, latest revision, “Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems.” This interface shall provide the functions identified in this section.

2.3.3.2.1 Enable trainline power as primary power supply

1. A PSC shall determine and indicate to the lead HEU that it is available as a primary trainline power supply only if all of the following conditions are true:
   a. Trainline voltage measured at the PSC is less than 10 VDC with either polarity.
   b. The PSC has received one or more HEU beacons in the past 6 s.
   c. The PSC has not detected a disabling fault (e.g., very low input voltage from the locomotive).
   d. The PSC has not been commanded to a cut-out state by the HEU.
2. A PSC shall enable its associated trainline power supply as the primary trainline power supply when the following conditions are true:
   a. A PSC has determined that it is available as a primary trainline power supply.
   b. The last HEU beacon received has the power control flag set to ON.
   c. The PSC has received an individual command from the HEU to enable the trainline power supply as a primary after the HEU beacon power control flag was set to ON.

2.3.3.2.2 Enable trainline power as secondary power supply

1. A PSC shall determine and indicate to the lead HEU that it is available as a secondary trainline power supply only if all of the following conditions are true:
   a. Trainline voltage measured at the PSC is greater than 50 VDC with a detectable DC polarity.
   b. The PSC has received one or more HEU beacons in the past 6 s.
   c. The PSC has not detected a disabling fault (e.g., very low input voltage from the locomotive).
   d. The PSC has not been commanded to a cut-out state by the HEU.

2. A PSC shall enable its associated trainline power supply as a secondary trainline power supply when the following conditions are true:
    a. A PSC has determined that it is available as a secondary trainline power supply.
    b. The last HEU beacon received has the power control flag set to ON.
    c. The PSC has received an individual command from the HEU to enable the trainline power supply as a secondary after the HEU beacon power control flag was set to ON.

2.3.3.2.2.1 Load-sharing capable trainline power supply

All trainline power supplies shall be load-sharing capable.

2.3.3.2.3 Disable trainline power

1. A PSC shall automatically disable its associated trainline power supply output if any of the following conditions are true:
    a. The PSC has received no HEU beacons in the past 6 s.
    b. The HEU beacon has the power control flag set to OFF.
    c. The PSC receives a command from the HEU to disable trainline power.
    d. The PSC detects a disabling fault (e.g., uncontrolled signal transmissions, very low input voltage from the locomotive). The PSC shall then send an exception message to the HEU.
    e. The PSC detects less than 100 VDC ±4 percent at its output while supplying its maximum rated current output (i.e., shorted trainline). The PSC shall then send an exception message to the HEU.
    f. The PSC upon being enabled as primary detects less than 110 VDC at its output within 10 s after receipt of the Enable command. The PSC shall then send an exception message to the HEU.
    g. The PSC, upon being enabled as secondary, detects that it is not properly sharing the trainline load at its output within 10 s after the receipt of the Enable command. The PSC shall then send an exception message to the HEU.

2.3.3.2.4 PSC status flags for power management

1. A PSC shall provide the following flags in its status response to allow the HEU to manage trainline power:
    a. Available for use as the primary trainline power supply (see Section 2.3.3.2.1).
    b. Available for use as a secondary trainline power supply (see Section 2.3.3.2.2 and Section 2.3.3.2.2.1).
    c. Trainline power supply input voltage below locomotive-specific threshold. This shall be a threshold voltage defined in the locomotive ID module to indicate the inability of the locomotive electrical system to continuously operate a trainline power supply at rated output. The locomotive ID module shall also include a second, higher threshold value to provide hysteresis for this flag. The default values for these threshold voltages shall be 50 and 60 V.
2. The remaining PSC status response data shall be as defined in Section 2.3.17.5.

2.3.3.3 HEU trainline power management

The HEU shall provide a control and status interface to the PSC via the trainline in accordance with the requirements of APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems." This interface shall provide the functions identified in this section.

2.3.3.3.1 Trainline power on/off control

The HEU shall control the on/off state of the trainline power supplies via the power control flag in the HEU beacon and individual commands to PSCs. The power control flag in the HEU beacon when set to the OFF state shall disable all PSCs as a group and prevent them from responding to Enable commands. A command to disable individual PSCs also shall be available. Individual commands shall be used to enable a PSC when the power control flag in the HEU is set to the ON state. An Enable command to secondary PSC(s) shall be sent only after the primary was successfully activated.

2.3.3.3.2 Locomotive power management

The HEU may optionally use the PSC status responses to select PSCs to provide ECP trainline power while minimizing the effect of the ECP system on the locomotive power system. The HEU may use the following criteria in determining PSCs to enable:

1. If a PSC indicates that its input voltage is below the locomotive-specific threshold, then it shall not be enabled if there is any other PSC available with input voltage above the threshold.
2. If multiple PSCs indicate input voltage above the locomotive-specific threshold, then the HEU may select PSCs based on the results of the ECP diagnostic test or other data. The criteria could include the following:
    a. PSC located on a locomotive other than the lead. This accounts for the likelihood that the lead locomotive has a larger electrical load for other than the ECP system.
    b. PSC that provided the highest average EOT node and lead locomotive measured trainline voltage during diagnostic tests. This minimizes the trainline cable losses.
    c. Multiple PSCs may be enabled by the HEU if they meet the requirements of Section 2.3.3.2.2 and Section 2.3.3.2.2.1. HEU logic in selecting multiple PSCs to enable may be manufacturer-specific.
3. If all available PSCs indicate input voltage below the locomotive-specific threshold, then the HEU may enable one or more PSCs using a manufacturer-specific algorithm. After operating for 15 min with PSC(s) indicating low input voltage, the HEU may command the CCDs on the trainline to limit their input power to less than 5 W average as defined in Section 2.3.13. The HEU shall warn the engineer of this condition. If a PSC indicates that its input voltage is above the locomotive-specific threshold, then it shall be enabled, PSCs with low input voltage shall be disabled and the CCDs shall be commanded back to their normal power input mode.

2.3.3.3.2.1 HEU multiple PSC management

When there are multiple PSCs available in a train, the lead HEU shall first attempt to enable the PSC that is located on the lead locomotive as a primary power supply (Section 2.3.3.2.1).

If the lead locomotive's PSC cannot be enabled as a primary power supply, the HEU shall inform the engineer of the locomotive road number corresponding to the next available PSC. The HEU shall require the engineer's confirmation that this locomotive is in the train before enabling its PSC as a primary and turning trainline power on.

2.3.4 Train brake commands

2.3.4.1 The HEU brake controller shall provide the engineer with a means for making the following braking commands:

- Full brake release
- Graduated brake release
- Minimum service brake application
- Graduated service brake application
- Full-service brake application
- Emergency brake application
- Suppression

2.3.4.2 The train brake commands determine the level of brake application for electronically controlled brake systems and shall be expressed as a percentage from 0 to 100 percent of full-service braking force in 1 percent increments. A 100 percent TBC shall be for full service, and 0 percent shall be for full release. Minimum service shall be at 10 percent, and an emergency brake application (whether intentional or the result of a fault or penalty) shall result in a TBC of 120 percent. When operating in passenger mode and an emergency application is commanded, the CCDs shall command an emergency service pressure defined in the CCDs' static data.

2.3.4.3 A suppression brake application shall be railroad-specific and programmed into the locomotive ID module. The default suppression brake application shall be full service.

2.3.5 Minimum service application

The minimum service brake application shall be at TBC = 10 percent. The minimum service brake cylinder pressure (MSP) is a preset value programmed into the car ID module. Minimum service brake cylinder default is 10 psig if no other value is provided in the car ID module.

2.3.5.1 Snow brake application

> **NOTE:** In conventional operations, this function is only available by discrete trainline.

The snow brake function shall be initiated by the HEU and communicated to the CCDs via the HEU beacon.

When operating in ECP mode, the CCD may implement on an application-specific basis the ability to perform snow braking.

When a CCD that supports snow braking is receiving the snow brake command, the brake system shall respond in such fashion to allow for slack adjustment.

If a vehicle receives a TBC greater than zero while a snow brake application is being commanded, then the CCD shall use the larger of the two target pressures.

2.3.6 Full-service brake cylinder pressure

2.3.6.1 Loaded full service pressure

The CCD shall have a full-service pressure parameter that is configured for customer-specific braking requirements.

2.3.6.2 Empty full service pressure

The CCD may use an empty full-service pressure parameter that is configured for customer-specific braking requirements.

2.3.6.3 Targeted full-service pressure

When operating in ECP mode, the CCD shall target a full-service brake cylinder control pressure based on the load weigh value per Section 2.3.9.

2.3.7 Emergency brake cylinder pressure

When the CCD is in ECP passenger mode, the target emergency service pressure shall be configured as a percentage of the targeted full service control pressure.

2.3.8 CCDs determine car load value

Passenger ECP vehicles shall locally perform any required load weigh braking and are not required to report the load weigh status to the HEU. In the absence of load weigh data or when not equipped with a load weigh device, the default brake command will be the fully loaded brake cylinder pressures. If controlled electronically, the load weigh brake cylinder correction shall be mapped linearly to a value between the empty and loaded brake cylinder control pressures defined in the static data.

2.3.9 Adjustment of BCP to train brake command

2.3.9.1 The brake cylinder pressure curve for TBC vs. BCP is determined based on the Min-Service and the calculated Full-Service and Emergency BCP(s) for a given car weight. The following formulas are used to determine this BCP curve.

Train Brake Command (TBC)	Brake Cylinder Pressure (BCP)
0%	BCP = 0 psi
0 < TBC ≤ 10%	BCP = MSP (Min-Service BCP, per Section 2.3.5)
10 < TBC ≤ 100%	BCP = m(x) + b where m = (FSP − MSP) / (100 − 10) b = FSP − m(100) x = TBC
TBC = 100%	BCP = Full-Service BCP, per Section 2.3.6
TBC > 100%	BCP = Emergency BCP, per Section 2.3.7

2.3.9.2 Other algorithms may be used to derive service BCP on less than fully loaded cars.

2.3.10 Brake cylinder pressure control

Vehicles shall control brake cylinder pressures according to the following performance requirements. All timing requirements are measured from the time the vehicle has received the TBC.

1. Steady-state BCP regulation shall be within ±3 psi of the final commanded target pressure.
2. The BCP control shall be as follows:
   - **Minimum service application:** BCP shall reach the target pressure, from a full release, within ±3 psi in no more than 2 s.
   - **Full-service application:** BCP shall reach the target pressure, from a full release within ±3 psi in no more than 6 s nor less than 4 s.
   - **Emergency service application:** BCP shall reach the target pressure, from a full release within ±3 psi in no more than 3 s nor less than 1.5 s.
3. Full-service release performance: When commanded to a zero TBC, the BCP shall reduce to less than 5 psi in no more than 7 s nor less than 3 s.

2.3.11 Mechanical brake cylinder and reservoir venting

> **NOTE:** In order to meet the intent of this section, it is recommended that a passenger car provide a means of cutting out the main reservoir or brake cylinder to allow the pressure to be vented fully by the system.

A method shall be available to manually vent brake cylinder pressure and reservoir pressure at every CCD location from both sides of the car without reliance on electronic activation or electronic control. It shall be possible to vent the brake cylinder pressure independently of the reservoir pressure, but not vice versa.

> **NOTE:** It is important to recognize that the brakes may still apply on a car that has its dirt collector cutout cock in the closed/isolated position when operating in ECP, and that the reservoirs must also be drained before a maintenance action is initiated.

The following requirements are listed in no particular order:

1. The brake cylinder release valve shall be capable of releasing air pressure from all brake cylinders of air brake equipment regardless of the charge state of the brake pipe.
2. The brake cylinder release valve shall be capable of being manually actuated to Release position by a single momentary pull of a release rod, from either side of the car, without requiring that the rod be held until brake cylinder pressure has been depleted.
3. When electrically cut in, a CCD in the brake cylinder venting state shall generate an Incorrect Brake Cylinder exception in accordance with Section 2.4.10.
4. The reservoir air pressure shall be released by holding the release rod in the activated position. When electrically cut in and the reservoir has vented, the CCD shall become inoperable and shall generate a Low Reservoir exception in accordance with Section 2.4.6.
5. The brake cylinder release valve shall not release brake cylinder pressure during any brake application except under the circumstances of actuation by the release rod.
6. When activated while the brakes are applied, the brake cylinder release valve shall prevent the further flow of air from the reservoir to the brake cylinder.
7. The car's pneumatic backup shall remain functional in accordance with Section 2.3.18 when the brake cylinder release valve has been activated.
8. When the manual release is activated while the brake pipe is charged and the brakes are applied, the following events will occur:
    - Brake cylinder pressure will not reapply if the brake pipe remains charged and TBC remains non-zero.
    - Brake cylinder pressure will reapply when the brake pipe is vented due to pneumatic backup.

    The brake cylinder release valve shall reset automatically to reestablish the normal operating connection to the brake cylinder once brake pipe pressure has been restored and any of the following occur:
    - Train brake command (TBC) = 0 percent
    - Brake pipe is subsequently vented
    - CCD is shut down and then powered up
    - The engineer reinitializes the train (Section 2.2.3)
    - During RUN mode, the engineer commands the CCD to individually cut in.
9. The brake cylinder release valve shall not permit air to flow from the reservoir to the brake cylinder while resetting.
10. The brake cylinder release valve may automatically reset upon depletion of reservoir pressure by leakage or otherwise, but it shall not permit development of brake cylinder pressure sufficient to set all brake shoes against the wheels of the car.

2.3.12 CCD cut out/cut in

When the CCD receives a CUTOUT mode HEU beacon, it shall transition to emulation mode per Section 2.2.8.

2.3.12.1 Under certain conditions, a CCD may cut out on its own or be commanded to cut out by the HEU. When a CCD cuts out, it releases its ECP brake application and relinquishes control of brake cylinder pressure to the pneumatic backup (See Section 2.3.18). If brake pipe is charged and a pneumatic application is not in effect, then brake cylinder pressure will release; otherwise it will remain at the level commanded by the pneumatic backup. When cut out, the CCD continues to charge its reservoir. If capable, a cut-out CCD will continue to transmit its status to the HEU in response to the polling cycle; however, it will not respond to the brake command. A CCD that reports a status of cut out will be considered inoperative by the HEU. A CCD that is cut out is polled only once per polling cycle by the HEU.

Under certain conditions (including Section 2.4.2.3 and Section 2.4.12.1), the HEU may automatically (without engineer action) command individual CCD(s) to cut out. In RUN mode, the HEU shall automatically command CCDs to cut out only if the low percent operable penalty brake application is not active.

2.3.12.2 A CCD shall cut out for the following reasons:

1. HEU commands a single CCD to cut out. This command is initiated by the engineer or the HEU.
2. CCD detects a critical loss and determines that it is isolated.
3. Other CCD faults.
4. CCD detects that its transceiver is generating uncontrolled signal transmissions.
5. CCD detects low battery charge and trainline power is not available.
6. CCD detects default or incorrect car static data (reference Section 2.4.12.1).

2.3.12.3 Except when the train operating mode is set to CUTOUT, when a CCD cuts out, it shall transmit an exception message to the HEU if capable. If the CCD is operating on an overlay-equipped car without stuck brake protection, a visual and audible warning shall be given to the train engineer anytime a CCD is cut out or cuts out for any reason. This warning shall be acknowledged. While cut out, a CCD shall suppress noncritical exception messages except for incorrect BC pressure (due to a BCP stuck brake).

While cut out, a CCD shall continue to monitor its BC pressure. If the CCD detects incorrect BCP (due to a BCP stuck brake; reference Section 2.4.10), then the CCD shall generate an Incorrect BCP exception.

2.3.12.4 Once a CCD is cut out, it shall remain cut out until one of the following occurs:

1. The HEU commands a single CCD to cut in. This command is initiated by the engineer or the HEU.
2. CCD cuts in if it detects (via HEU beacon) that the operating mode was changed from CUTOUT to another mode.
3. A CCD with fault detects that the fault condition is cleared. However, the HEU still considers such a CCD as cut out and inoperative until the HEU determines that the CCD is cut in.
4. HEU reinitializes train.

2.3.13 CCD/EOT node power system

2.3.13.1 The power on each CCD/EOT node shall be maintained through a rechargeable battery system (refer to APTA PR-M-S-023-19, "ECP Passenger Cable-Based Brake DC Power Supply—Performance Requirements," latest revision. Batteries are continuously charged from the trainline while it is energized via an onboard battery charger. In case of trainline power failure and local car battery power, CCDs and EOT nodes with fully charged batteries shall be capable of operating on battery backup power for at least 4 h. The battery backup system within a CCD may be configured to allow the device to operate normally from trainline power with a fully discharged, failed or missing battery. A CCD in this condition may be considered as operative for the calculation of percentage operable brakes until the combined total of CCDs in this condition and other inoperative CCDs exceeds the penalty brake threshold. Refer to Section 2.4.8, "CCD or EOT node detects low battery charge," for fault response.

2.3.13.2 Power consumed by each battery charger/CCD shall be limited to 50 W peak. The EOT node shall be limited to 20 W peak.

2.3.13.3 The passenger ECP system shall have the ability to operate off of the local car power. The local car power shall be used when operating in emulation mode and when trainline power is not available in ECP operation.

2.3.14 Network device input characteristics

The input impedance of any network device shall be nominally 2000 ohms in the 100 to 450 KHz frequency band in receive mode.

2.3.15 Network device output characteristics

Output conducted emissions on the trainline shall generally meet the requirements of FCC Section 15.107. Specifically, the conducted emissions as measured on the trainline in differential mode may not exceed 106 dBμV from 9 to 40 kHz; 86 dBμV from 40 to 125 kHz; 36 dBμV from 125 to 140 kHz; 56 dBμV from 140 to 450 kHz; and 48 dBμV from 450 kHz to 30 MHz.

2.3.16 CCD or EOT node in shutdown mode

Shutdown mode (or "battery conservation" mode) shuts off the EOT node to minimize battery drain. When shut down, the EOT node is turned off. When a CCD shuts down, it releases its ECP brake application and relinquishes control of brake cylinder pressure to the pneumatic backup. If the brake pipe is charged and a pneumatic application is not in effect, then brake cylinder pressure will release; otherwise it will remain at the level commanded by the pneumatic backup. When an EOT node shuts down, it stops transmitting EOT beacons. Once trainline power is lost, the CCD or EOT node either continues to operate off of battery power until its battery runs low or enters into a timed shutdown mode. The intent of this logic is to allow the train to operate as long as possible after a loss of trainline power and to conserve batteries if the device is disconnected from the trainline, the train is parked or the ECP brake system is cut out.

- The EOT node shall remain in a timed shutdown process while both trainline power and HEU beacons are not present.
- If brake pipe pressure is less than 5 psi, the EOT node shall shut down in 2 min; otherwise, the EOT shall shut down in 1 h.
- The EOT node shall shut down immediately after the trainline power is lost and the train operating mode is set to CUTOUT.

When the CCD ends ECP mode, it shall transition to emulation. If trainline power and local power are lost, then the CCD shall operate off of the backup battery until the backup battery runs low.

2.3.17 Messaging requirements

These requirements are covered in detail in APTA PR-M-S-024-17, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems," latest revision. The following sections are intended to give a brief description.

2.3.17.1 HEU beacon

The HEU beacon shall be a priority message broadcast by the HEU once per second (1.0 Hz) and shall contain a unique identifier, train brake command, and a network device status query, among other information, as described in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

2.3.17.1.1 Train brake commands

A TBC shall be broadcast as part of the HEU beacon and shall be a percentage of full-service braking force: 0 percent shall be full release; 10 percent shall be minimum service application; 11 to 99 percent shall be graduated service; 100 percent shall be full service; and 120 percent shall be emergency braking.

2.3.17.1.2 Network device status query

Each HEU beacon shall include a status query for an individual network device (trail HEU, PSC or CCD) during RUN mode. The network device status query shall be used by the ECP brake system to periodically verify communications and control between the HEU and all network devices on the train. It also shall gather data for diagnostic and event recording purposes. Network devices shall be queried for their operating status on a round-robin basis by the HEU. During each round-robin cycle, all CCDs, all active PSCs and at least one inactive device (trail HEUs and standby PSCs) shall be queried. Status queries to all inactive devices shall be completed on successive round-robin polling cycles. With the transmission of each HEU beacon once per second, the HEU will query a different network device by transmitting its address and a request for its status.

2.3.17.2 Train configuration command

Once every 120 s and upon setup changes, the HEU shall broadcast a Configuration Command message. This message shall contain the current BP set point and other information as defined in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

2.3.17.3 CCD status messages

When a CCD is queried, it shall transmit the following information:

1. Brake pipe pressure
2. Percentage brake applied (BCP relative to full-service application)
3. Reservoir pressure
4. Cut-in/cut-out status
5. Other information as identified in APTA PR-M-S-024-17, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems," latest revision.
6. Brake cylinder pressure
7. Battery percentage charged:
    a. To be sent as a value in the range of 0 to 100 percent in 10 percent increments
    b. 20 percent or less shall be defined as a low battery
    c. 100 percent shall be defined as a fully charged battery
8. Trainline power status (ON/OFF). The CCD shall report a trainline power status of ON when it is powered from the trainline; otherwise it shall report a trainline power status of OFF.

Some of this information may be recorded by the locomotive's event recorder and/or made available for display to the engineer. To give "percent brake applied" status, the CCD shall compute the percentage of full-service BCP applied during each status query.

> **NOTE:** EOT node brake pipe pressure is not required to be valid.

2.3.17.3.1 Train brake effort (TBE)

When in RUN mode, the percentage brake applied reported by the CCDs is used to determine the train brake effort (TBE).

TBE is a determination by the Lead HEU of the combined braking effort of all the CCDs in the train for the purpose of providing feedback to the train operator. This determination takes into account CCDs that are cut in, cut out or not responding. The TBE for cut-out cars is tracked separately from the cut-in cars, and then the final TBE is determined based on the following formula:

$$\textit{TBE Train} = \frac{(\#\ \textit{of cut-in CCDs} \times \textit{TBE cut in}) + (\#\ \textit{of cut-out CCDs} \times \textit{TBE cut out})}{\textit{Total}\ \#\ \textit{CCDs}}$$

where:

TBE cut in = a weighted average of the previous TBE cut in and the percentage brake applied of the last cut-in CCD polled

TBE cut out = a weighted average of the previous TBE cut out and the percentage brake applied of the last cut-out CCD polled

Last CCD polled is weighted twice as much as the previously calculated TBE.

This is expressed with the following formula:

$$\textit{TBE cut in} = \frac{\textit{TBE cut in} + (2 \times \textit{PBALast cut-in CCD polled})}{3}$$

$$\textit{TBE cut out} = \frac{\textit{TBE cut out} + (2 \times \textit{PBALast cut-out CCD polled})}{3}$$

where:

PBA= percentage brake applied as reported by the CCD

CCDs reporting a percentage brake applied of Unknown or not responding to the poll are not included in the calculation of TBE cut in or TBE cut out, but are included in the overall TBE calculation based on the number of CCDs cut in and number of CCDs cut out. A CCD that does not respond to a poll is considered cut out.

The TBE shall be displayed on the lead locomotive with a resolution of 1 percent.

2.3.17.4 EOT beacon/status message

The EOT beacon shall be a priority message transmitted to the HEU once per second (1.0 Hz) and shall contain a status message that includes the brake pipe pressure, percentage of full battery charge, trainline voltage and other information as identified in APTA PR-M-S-024-19, latest revision, “Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems.” This information may be recorded by the locomotive’s event recorder and/or made available for display to the engineer. The brake pipe pressure at the EOT node may be displayed if provided continuously to the engineer via the HEU.

2.3.17.5 PSC status message

When a PSC is queried, it shall read and transmit the following quantities:

1. Status data
2. Trainline voltage
3. Other information as identified in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems"
4. Input voltage
5. Output current

Some of this information may be recorded by the locomotive's event recorder and/or made available for display to the engineer.

2.3.17.6 Trailing HEU status message

When a trailing HEU is queried, it shall read and transmit the following quantities:

1. Status data
2. Other information as identified in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems"

Some of this information may be recorded by the locomotive's event recorder and/or made available for display to the engineer.

2.3.17.7 Exception messages

A network device shall generate an exception message when and as required by Section 2.4 of this document and by APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

2.3.17.8 Control messages

Control messages are generated by the HEU to command CCDs, PSCs or EOT node to operate in certain ways. They include the following:

- CCD cut-in/cut-out
- Operating mode
- Train initialization and sequencing
- PSC enabled/disabled
- Version compatibility

Other messages concerning car health monitoring and distributed locomotive control are covered by APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

2.3.18 Pneumatic backup

2.3.18.1 Each car shall have a means of propagating a pneumatic emergency and of pneumatically applying emergency brake cylinder pressure (i.e., requiring no electrical power). The pneumatic backup system shall always be capable of providing emergency brake cylinder pressure (assuming reservoirs are adequately charged) in the event of a pneumatic emergency, whether or not the CCD is operational.

2.3.18.2 The pneumatic backup (PB) system shall include an AAR-approved (or equivalent) pneumatically controlled brake pipe emergency venting device that shall be required on all ECP-equipped cars, whether a "pure" ECP or an overlay system is used. Said emergency venting device(s) shall always be active (enabled) when connected to the brake pipe; however, they shall not undesirably vent BP in response to typical service fluctuations of BP, either when the ECP is operational or during pneumatic operation in an overlay system. The pneumatic backup equipment shall conform to existing AAR specifications for emergency venting devices as follows:

- Spacing in accordance with the section titled "Additional Equipment for Cars with Brake Pipe Length in Excess of 75 ft" in AAR Standard S-401, "Freight Car Brake Design Requirements."

  NOTE: The words "control valve" refer to the emergency venting device for ECP operation.

- Triggering (by the rapid venting of BP to zero) compliant APTA PR-M-S-005-98, latest edition, "Code of Tests for Passenger Car Equipment Using Single Car Testing."

2.3.18.3 When possible, electronic CCD operation shall take precedence over or assist the pneumatic backup in controlling BCP. Operating CCDs shall sense loss of BP (see Section 2.4.3.3) and respond accordingly. CCDs that may not be able to completely take precedence over pneumatic backup (e.g., overlay CCDs, CCDs not communicating with the HEU but still powered by the trainline) shall assist in controlling BCP to the emergency pressure appropriate to car loading (see Section 2.3.8).

2.3.18.4 The pneumatic backup must remain active when a CCD has been cut out, disabled or shut down, or has stopped receiving the HEU beacon. A pneumatic emergency brake application shall be released when the brake pipe pressure has increased between the initial application threshold and the remaining reservoir pressure or when electronic CCD operation has taken precedence.

> **NOTE:** Cars at any load not equipped with a pneumatic empty/load device will apply emergency brakes at the loaded car pressure when the pneumatic backup applies the brakes.

2.3.18.5 Pneumatic backup brake performance

2.3.18.5.1 The pneumatic backup (PB) application shall always be available irrespective of the existing state of ECP operation, providing that no mechanical isolation of the brake pipe signal by means of dirt collector cut-out cocks has been established.

2.3.18.5.2 The pneumatic backup transmission rate shall exceed 750 ft/s on an AAR standard 150-car test rack.

2.3.18.5.3 The pneumatic backup brake cylinder buildup time shall meet the requirements of an ECP emergency application and shall be no more than 12 s nor less than 7 s.

2.3.18.5.4 With any group of three consecutive PB-equipped, 85 ft cars pneumatically cut out, an emergency reduction of brake pipe pressure shall cause the remainder of the PB-equipped cars to operate in emergency.

2.3.19 Continuous reservoir charging

The car brake system supply reservoir shall be charged continuously from either the brake pipe or the main reservoir. The brake pipe is not the primary mode of charge and is used as a backup. Airflow from the main reservoir or brake pipe to the supply reservoir shall never be interrupted; however, a mechanism shall be provided to prevent reversal of flow from the supply reservoir to the main reservoir or brake pipe.

2.3.19.1 Control valve charging shall be an equivalent size so that a 6000 cu in. reservoir will reach 85 psi in 410 to 480 s when charged from a 90 psi brake pipe pressure.

2.3.20 Other equipment operating as an EOT node

> **NOTE:** In passenger ECP systems, the capability to read the BP is not required for a locomotive, cab car or ECP vehicle.

2.3.20.1 The ECP equipment on the last ECP vehicle in the train, if it is also the last vehicle in the train, may perform the functions of the EOT node as defined in this document and in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

2.3.20.2 The ECP equipment on a locomotive shall automatically enable the EOT node function if the following conditions are met:

1. The last vehicle ECP equipment is capable of measuring trainline voltage.
2. The last vehicle ECP equipment detects the presence of the trainline termination.
3. The last vehicle ECP equipment is not on the lead locomotive.
4. The last vehicle ECP equipment is receiving HEU beacons.
5. The last vehicle ECP equipment is not receiving EOT beacons.

2.3.20.3 Once the EOT node function has been enabled for an ECP device, that device shall continue to perform the EOT node function until one of the following conditions is met:

1. Trainline power is lost and no HEU beacons are detected for more than 1 h.
2. Trainline power is lost and the train operating mode is set to CUTOUT.
3. EOT beacons from another ECP network device, an EOT node or another ECP device are detected on the trainline.

2.3.20.4 The purpose of the requirements in this section is to support a train that is operating with the last vehicle in the train is a locomotive, cab car or ECP vehicle. To provide locomotive brake control for critical loss penalties, the last vehicle functioning as the EOT node shall be capable of detecting an ECP critical loss and providing local brake cylinder control.

2.3.20.5 ECP equipment functioning as the EOT node shall perform the normal EOT node fault response and recovery as specified in Section 2.3.20.6 and Section 2.4.

2.3.20.6 Locomotive, cab car or ECP vehicle as ECP EOT loses trainline termination

If the last vehicle ECP equipment functioning as the EOT node detects the removal or loss of its trainline termination, then it shall stop transmitting EOT beacons.

2.3.21 Cab car functionality

2.3.21.1 Cab car as a CCD

The cab car shall always support the requirements of a passenger CCD and be counted as an operable brake with the following exception:

1. If the battery percentage is not available, then the cab car shall report a 100 percent battery charge percentage.

2.3.21.2 Cab car as an HEU

When operating as lead HEU, the cab car shall perform the functions of a lead HEU. When operating as a trailing device, the cab car shall not respond as a trailing locomotive.

2.4 Fault response and recovery functions

The following fault modes (response functions) apply to both pure ECP and overlay operation. All fault-induced brake applications must remain in effect for 60 s or until the train has stopped before recovery procedures (see Section 2.4.16) can be initiated. Operating mode changes can be made only after the train is stopped or after the 60 s timer has expired (see Section 2.2.2.1).

When a CCD, PSC or EOT node (including locomotive ECP equipment functioning as an EOT node) experiences multiple faults, only the most serious fault shall initially be reported and acted upon. Only when this fault is cleared shall the lower priority faults be acted upon. The hierarchy of fault severity shall be as shown in **Table 2**.

TABLE 2

CCD, PSC and EOT Node Fault Hierarchy and Exception Priority

Fault Degree	Type of Fault	Fault
1	Fault that may immediately disable the entire ECP control network	• CCD/EOT/PSC transceiver generates uncontrolled signal transmission
2	Fault that may cause a penalty or emergency brake application	• CCD/EOT detects critical system loss • PSC detects multiple HEUs • EOT detects low battery charge
3	Fault that may cause system degradation	• EOT detects low BP • PSC detects loss of HEU beacon • EOT or PSC detects low/high trainline voltage • PSC detects trainline short circuit • PSC detects low input voltage • PSC detects enable fault
4	Fault that may disable a single CCD, PSC or EOT	• CCD detects incorrect BC pressure • CCD detects low reservoir pressure • CCD detects low battery charge • CCD, PSC or EOT detects other manufacturer-specific self-diagnostic fault • CCD detects a car ID fault

The HEU, upon receiving CCD, PSC, trailing HEU or EOT node exception messages and/or generating its own exceptions, shall prioritize them as shown in **Table 3**. When the HEU detects a fault condition, the highest priority condition is acted upon first. Lower priority faults are handled only after high-priority faults are cleared.

When an emergency brake application is active, a CCD shall suppress all exception messages except for Critical Loss exception messages. Recovery from an emergency brake application shall cause all CCD, trailing HEU and EOT node fault logic to be reset and/or enabled.

Exception-clear messages shall be allowed when the HEU is commanding an emergency. Exception messages from a PSC shall be allowed in any mode.

Note that unless the ECP EOT node brake pipe pressure is known, the exceptions related to low brake pipe and loss of brake pipe pressure from the EOT node will not apply.

TABLE 3
HEU Fault Hierarchy and Exception Priority

Fault Degree	Type of Fault	Fault
1	Fault that may immediately disable the entire ECP control network	• HEU transceiver generates uncontrolled signal transmission
2	Fault that requires an emergency brake application	• Two CCD/EOTs report critical loss within 5 s • HEU misses EOT beacon when in RUN mode • Crew commands an emergency brake application
3	Fault that requires a full-service brake application.	• <50% operative brakes detected • EOT reports low battery charge • Penalty brake application • EOT reports critical loss • PSC reports detection of multiple lead HEUs
4	Fault that indicates multiple brakes may eventually be disabled.	• <95% operative brakes detected • <90% operative brakes detected • <85% operative brakes detected • <75% operative brakes detected • CCD reports low reservoir pressure • CCD goes offline (or cuts out) • CCD reports low battery charge • EOT or PSC reports low or high trainline voltage • EOT reports low brake pipe pressure • PSC reports other disabling fault
5	Individual device faults	• CCD detects incorrect BCP • PSC or trail HEU fails to respond to status query • CCD/EOT/PSC/trail HEU detects other self-diagnostic fault

2.4.1 System fault-initiated brake applications

2.4.1.1 Conditions causing fault-initiated emergency (as differentiated from penalty and intentional) application are described in the following sections:

- HEU transceiver generates uncontrolled signal transmission (see Section 2.4.2.7)
- HEU misses EOT beacon when in RUN mode (see Section 2.4.2.1)
- HEU receives at least two Critical Loss exception messages from CCDs or EOT node (see Section 2.4.4.3)
- CCDs may self-initiate an emergency brake application in response to multiple CCDs and/or EOT node detecting a critical loss (see Section 2.4.4.1)

2.4.1.2 Conditions causing a fault initiated full-service application are described in the following sections:

- HEU registers less than 50 percent operative brakes (see Section 2.4.5.2)
- EOT node low battery charge (see Section 2.4.8)

2.4.1.3 Conditions causing a penalty full-service brake application are described in the following sections:

- HEU receives Critical Loss message from EOT node (see Section 2.4.4.5)
- PSC reports detection of multiple lead HEUs (see Section 2.4.11)

2.4.2 Signal transmission faults

2.4.2.1 HEU misses EOT beacon (RUN mode only)

If the HEU fails to receive the EOT beacon for 6 s, the engineer shall be given an audible and visible warning and the HEU shall automatically command an emergency brake (TBC = 120 percent) command and transmit a "trainline power-off " command (see Section 2.3.3.1.2).

2.4.2.1.1 Recovering from a missed EOT beacon fault

2.4.2.1.1.1 If an HEU in this fault condition subsequently receives the EOT beacon, then the fault is cleared and the HEU will enable system recovery as described in Section 2.4.13. Loss of the EOT beacon for more than 15 s while in RUN mode shall require a reinitialization of the train.

2.4.2.1.1.2 If the EOT beacon cannot be restored, then the engineer may change mode.

2.4.2.2 Failure to receive HEU beacon

2.4.2.2.1 CCD or EOT node or trailing HEU misses HEU beacon

If any CCD, trailing HEU or EOT node fails to receive the HEU beacon for 6 s, then the CCD or trailing HEU shall maintain the current brake application and the CCD, trailing HEU or EOT node shall broadcast a Critical Loss exception message (see Section 2.4.4).

2.4.2.2.1.1 Last ECP vehicle EOT node function loses HEU beacon

If the ECP equipment functioning as the EOT node fails to receive the HEU beacon for 6 s, then the ECP equipment shall stop transmitting EOT beacons, transmit a Critical Loss exception message and make an electronic emergency brake application (see Section 2.3.1.5).

2.4.2.2.2 Clearing a CCD or EOT node or trailing HEU misses HEU beacon exception

If a CCD or EOT node or trailing HEU subsequently receives the HEU beacon, it shall clear this exception, but shall not transmit an exception-clear message. If the TBC in the HEU beacon is less than 120 percent, then all other critical exception logic shall also be reset. After communication with the HEU is restored, and the CCD or EOT node or trailing HEU has no other faults, it shall resume normal operation.

2.4.2.3 HEU does not receive CCD's response to status query (RUN mode only)

If the HEU does not receive a response from a CCD logged as cut in to a status query message, then the HEU shall repeat the status query (repoll the CCD) up to two times. If the HEU does not receive the CCD's response by the third query, then the CCD is logged as inoperative by the HEU, and the HEU transmits a CUTOUT command to the CCD in accordance with Section 2.3.12.1.

2.4.2.3.1 Recovery of a CCD that failed to respond to status query

If a CCD that is cut out because it failed to respond to the HEU status query responds to subsequent HEU status queries and reports that it is cut in, then the HEU shall log this CCD as operative.

2.4.2.4 HEU does not receive PSC's response to status query

2.4.2.4.1 If the HEU does not receive a response from a PSC to a status query message, then the HEU shall repeat the status query (re-poll the PSC) up to two times. If the HEU does not receive the PSC's response by the third query and it is an active PSC, then the PSC shall be commanded to an inactive state and another PSC shall be commanded to an active state (if available) to power the trainline.

2.4.2.4.2 If the HEU does not receive the PSC's response by the third query and it is an inactive PSC, then the HEU shall log the PSC as inoperative for the purpose of being available for activation.

2.4.2.4.3 If the PSC later resumes responding to the status query and has no other faults, then the HEU shall log the PSC as available for activation.

2.4.2.5 HEU does not receive trailing HEU's response to status query

2.4.2.5.1 If the HEU does not receive a response from a trailing HEU to a status query message, then the lead HEU shall repeat the status query (re-poll the trailing HEU) up to two times. If the lead HEU does not receive the trailing HEU's response by the third query, then the lead HEU shall log that trailing HEU as inoperative.

2.4.2.5.2 If the trailing HEU later resumes responding to the status query and has no other faults, then the lead HEU shall log the trailing HEU as operative.

2.4.2.6 PSC misses HEU beacon

If a PSC fails to receive the HEU beacon for 6 s, then it shall automatically de-energize its trainline power output and enter a disabled state. A PSC shall not broadcast a Critical Loss exception.

2.4.2.6.1 Clearing PSC misses HEU beacon exception

If a PSC subsequently receives the HEU beacon and the PSC has no other faults, it shall respond to subsequent status queries that it is available for activation.

2.4.2.7 Network device's transceiver generates uncontrolled signal transmissions

A means shall be provided within each network device on the trainline network to detect if it is transmitting improper signals or noise onto the communications network and to disable its transmitter within 1 s. This method shall detect the presence of improper signals and ascertain that the local transceiver is the source. It shall then interrupt the transceiver by commanding an immediate shutdown of the transceiver.

The device with the faulty transceiver shall cut out and shut down its transmitter within 1 s. The device may attempt to re-enable its transmitter a maximum of two times, with a minimum retry interval of 30 s, before shutting it down permanently. (Removal and reapplication of power shall allow the device to re-enable its transmitter subject to another shutdown if uncontrolled signal transmissions are detected.)

2.4.2.7.1 HEU transceiver generates uncontrolled signal transmissions

If the HEU's transceiver is the source of the fault, then the HEU shall shut off its transmitter and, if it is the lead HEU, it shall then warn the engineer.

2.4.2.7.2 PSC transceiver generates uncontrolled signal transmissions

If an enabled PSC's transceiver is the source of the fault, then the PSC shall shut off its transmitter, disable its trainline power output and enter an inactive state.

2.4.2.7.3 CCD transceiver generates uncontrolled signal transmissions

If a CCD's transceiver is the source of the fault, then the CCD shall shut off its transmitter and cut out.

2.4.2.7.4 EOT node transceiver generates uncontrolled signal transmissions

If an EOT's transceiver is the source of the fault, then the EOT node shall shut down its transmitter. Normal HEU fault logic shall then respond accordingly to the loss of EOT beacon.

2.4.2.7.5 Recovery procedure for uncontrolled signal transmission

The faulty device must be cut out or otherwise disconnected from the network. In the case of the HEU, another locomotive must be used as lead locomotive or the HEU must be replaced. In the case of the EOT node, the EOT node must be replaced or the system mode must be changed.

2.4.3 Low brake pipe pressure (only if known to be accurate)

2.4.3.1 EOT node detects low BP (only if BP is known to be accurate)

If an EOT node detects BP less than 0.67 × BP set point, then it shall transmit a Low BP exception message to the HEU.

2.4.3.1.1 HEU response to EOT node low BP (only if BP is known to be accurate)

The HEU shall detect low BP at the EOT node. On detection of low BP at the EOT node, the HEU shall give an audible and visual warning to the engineer. The HEU may detect low EOT BP either by receipt of an EOT Low BP exception message or based on information transmitted in the EOT beacon.

2.4.3.2 EOT node detects loss of BP (only if BP is known to be accurate)

If the EOT node detects BP less than 0.56 × BP set point, then it shall broadcast a Critical Loss exception.

2.4.3.2.1 Clearing an EOT Node Low/Loss of Brake Pipe Pressure exception (only if BP is known to be accurate)

The Low BP exception and/or Loss of BP exception shall be cleared when the EOT node detects that BP rises above 0.74 × BP set point. When the Low BP exception is cleared, the EOT node shall transmit an EOT Low BP Exception Cleared message to the HEU. When the Loss of BP exception is cleared, the EOT node shall transmit an EOT Loss of BP Exception Cleared message to the HEU.

2.4.3.3 CCD or trailing HEU detects loss of BP

Except when in a "no air" condition, if a CCD or trailing HEU detects a loss of BP, it shall broadcast a Critical Loss exception message. Loss of BP shall be defined as BP less than 0.56 × BP set point. A "no air" condition shall be defined as brake pipe pressure, reservoir pressure and brake cylinder pressure all less than 5 psi, which is normally associated with manual venting of reservoir and brake cylinder pressure.

2.4.3.3.1 Clearing CCD or trailing HEU Loss of BP exception

This exception shall be cleared when the CCD or trailing HEU detects that the BP rises above 0.67 × BP set point. When this exception is cleared, it shall not transmit a Loss of BP Exception Cleared message to the HEU.

2.4.3.4 HEU recovery from loss of brake pipe pressure

The HEU shall not allow recovery from a loss of brake pipe pressure as described in Section 2.4.4.6 until it detects that the loss of BP condition is cleared at the EOT node.

2.4.4 System-critical loss

A system-critical loss is defined as a loss of HEU beacon or a loss of BP.

Critical loss fault logic brake control specified in this section for trailing HEUs applies to ECP-equipped locomotives with the ability to provide locomotive retardation based on ECP brake applications as specified in Section 2.3.1.5.

2.4.4.1 Multiple CCDs, trailing HEUs or EOT node have critical loss

If a CCD or trailing HEU receives a Critical Loss exception within 5 s of experiencing a critical loss, or experiences a critical loss within 5 s of receiving a Critical Loss exception message, or receives Critical Loss exception messages from two other devices (CCDs or EOT node or trailing HEU) within 5 s, then that CCD or trailing HEU, if applicable (see Section 2.3.1.5), shall make an electronic emergency brake application.

CCDs or trailing HEUs that go into self-initiated emergency shall maintain their emergency application, regardless of the TBC in the HEU beacon, until the system-critical loss fault condition is cleared as described in Section 2.4.4.6.

2.4.4.1.1 Critical Loss Relay

If the HEU beacon is still being received, then CCDs or trailing HEUs that go into self-initiated emergency shall monitor the TBC in the HEU beacon for a period of 60 s ±10 s after it went into self-initiated emergency to ensure that the "critical loss" is propagated to the HEU.

If the TBC in the HEU beacon is not 120 percent within 5 s of self-initiating an emergency, then the CCD or trailing HEU shall broadcast a Critical Loss Relay exception. This process shall repeat every 5 s until the TBC in the HEU beacon is 120 percent, the 60 s monitoring period ends, or the CCD and trailing HEU critical loss fault logic is reset by the lead HEU.

The unique IDs of the first two devices generating a critical loss message shall be included in the critical loss relay message.

2.4.4.1.1.1 HEU receives Critical Loss Relay message

If the HEU receives one or more Critical Loss Relay exception messages, then it shall command an electronic emergency brake application (TBC = 120 percent) and provide a warning to the engineer.

2.4.4.1.1.2 CCD or trailing HEU receives Critical Loss Relay message

If a CCD or trailing HEU receives a Critical Loss Relay exception, then that CCD or trailing HEU shall make an electronic emergency brake application.

CCDs and trailing HEUs that go into self-initiated emergency shall maintain their emergency application, regardless of the TBC in the HEU beacon, until the system-critical loss fault condition is cleared as described in Section 2.4.4.6 and Section 2.4.4.6.1.

2.4.4.2 Isolated critical loss

If a CCD detects a critical loss (loss of HEU beacon or loss of BP) and does not receive a Critical Loss exception message from any other device within 5 s, then it shall assume the fault is local to the CCD and cut out as described in Section 2.3.12.

2.4.4.3 HEU receives at least two Critical Loss messages

If the HEU receives Critical Loss exception messages from two or more devices (CCDs or EOT node or trailing HEU) within 5 s, then it shall command an electronic emergency brake application (TBC = 120 percent) and provide a warning to the engineer.

2.4.4.4 HEU receives a single CCD Critical Loss message

If the HEU receives only one Critical Loss exception message (loss of HEU beacon or loss of BP) within a 5 s time period and it is from a CCD, then the HEU shall command that CCD to cut out (see Section 2.3.12).

2.4.4.5 HEU detects EOT node Critical Loss message

The HEU shall detect an EOT node critical loss. On detection of an EOT node critical loss, the HEU shall command a full-service brake application and provide a warning to the engineer. The HEU may detect an EOT node critical loss either by receipt of a single Critical Loss exception from an EOT node or based on information in the EOT beacon.

2.4.4.6 Recovery from system-critical fault

After the HEU has detected that the cause of the fault has been eliminated (as described in Section 2.4.2.1.1, Section 2.4.2.2.2, Section 2.4.3.4 and Section 2.4.3.5), the HEU shall command the system to reset fault processing and allow recovery as described in Section 2.4.13.

2.4.4.6.1 Clearing a CCD or trailing HEU system-critical fault

CCDs and trailing HEUs shall reset their critical fault logic on detection of an HEU-commanded critical fault reset, transition out of INIT mode, receipt of the HEU beacon with a TBC less than 120 percent after an HEU beacon loss event or on the detection of a transition in the train brake command from 120 percent to less than 120 percent.

2.4.5 Reduced percentage of operative brakes

In RUN mode, the HEU shall register as inoperative any CCD that is disabled for any of the following reasons:

- Communication lost (CCD status query not answered)
- Low battery charge with no external power
- Low reservoir charge
- CCD is cut out
- CCD cannot obtain a BCP of at least 5 psig after minimum service or greater is commanded (BCP cannot apply)

The HEU shall then compute the percentage of operative brakes based on the total number of potentially operative brakes determined during initialization and the number of remaining operative brakes. Fractional percentage operative computation results shall always be truncated down to the next whole percentage point.

CCDs that have a low or missing battery but are functional when external power is active shall be considered operative by the HEU for the purpose of calculating percentage of operative brakes as long as the combined total of these and other inoperative CCDs does not exceed the threshold that causes the HEU to command a penalty full-service brake application.

The following fault responses shall occur if the percentage of operative brakes falls below certain thresholds.

2.4.5.1 HEU registers less than 95 percent, 90 percent, 85 percent and 75 percent operative brakes (RUN mode only)

If the percentage of operative brakes falls below 95 percent, then the engineer shall be audibly and visually warned and given the current percentage operable. If the percentage falls below 90 percent, then the engineer shall likewise be warned and given the percentage. These warnings must be acknowledged by the engineer.

Warnings shall also be provided at 85 and 75 percent operable (as per CFR 238.15).

2.4.5.2 HEU registers less than 50 percent operative brakes (RUN MODE ONLY)

If the percentage of operative brakes falls below 50 percent, then the engineer shall be given a warning and the HEU shall command an electronic full-service brake application.

2.4.6 CCD low reservoir charge

If a CCD detects that its reservoir charge is less than 0.63 × BP set point, then it will transmit a Low Reservoir Charge exception message to the HEU.

2.4.6.1 Clearing the CCD Low Reservoir Charge exception

When the CCD detects that its reservoir charge exceeds 0.74 × BP set point, the fault is cleared and the CCD transmits a Low Reservoir Charge Exception Cleared message to the HEU.

2.4.6.2 HEU receives CCD Low Reservoir Charge message (RUN mode only)

When the HEU receives a CCD Low Reservoir Charge exception message, it shall record the occurrence and log the CCD as inoperative.

2.4.6.3 HEU receives CCD Low Reservoir Charge Exception Cleared message

When the HEU receives a CCD Low Reservoir Charge Exception Cleared message from a CCD, it shall record the occurrence and log the CCD as operative.

2.4.7 Low trainline voltage

When the trainline voltage falls below 100 VDC ±4 percent, the ECP brake system shall continue to operate, on battery power if necessary, as defined in Section 2.3.13.

2.4.7.1 EOT node or PSC detects low trainline voltage

If, after allowing a 45 s settling period after the HEU beacon power flag is set to ON, the EOT node or any PSC detects that trainline voltage is below 100 VDC ±4 percent, then it shall transmit a Low Trainline Voltage exception message to the HEU.

2.4.7.2 Clearing an EOT node or PSC Detects Low Trainline Voltage exception

When the EOT node or PSC that reported low trainline voltage detects that the trainline voltage has increased to more than 110 VDC ±4 percent, it shall clear this exception and transmit a Low Trainline Voltage Exception Cleared message to the HEU.

2.4.7.3 HEU receives Low Trainline Voltage Exception message

The HEU shall provide an audible and visual warning to the engineer that an EOT node or PSC detected that the trainline voltage is less than 100 VDC only when trainline power is activated. The audible warning shall cease when the engineer acknowledges the warning.

2.4.7.4 HEU receives Low Trainline Voltage Exception Clear message

When all Low Trainline Voltage exceptions have been cleared, the visual warning shall be removed.

2.4.8 CCD or EOT detects low battery charge

If a CCD or EOT node detects low battery charge with trainline power off, then it shall transmit a Low Battery exception message to the HEU at least 5 min before commencing an orderly shutdown as described in Section 2.3.16. With trainline power available, a CCD or EOT node shall transmit a Low Battery exception message if it detects that its battery would be incapable of powering the device in the event of a loss of trainline power. A CCD may continue to operate from trainline power if its batteries are unable to power it.

The CCD low battery charge threshold shall correspond to a battery percentage charged level of 20 percent.

2.4.8.1 Clearing the CCD or EOT node Low Battery Charge Exception message

When the CCD or EOT node with a low battery charge fault detects that its battery has recharged to a sufficient level, it shall transmit a Low Battery Charge Exception Cleared message to the HEU.

The CCD low battery charge clear threshold shall correspond to a battery percentage charged level of 30 percent.

2.4.8.2 HEU receives CCD Low Battery Charge Exception message

The HEU shall include CCDs reporting low battery charge in its calculation of inoperative CCDs.

2.4.8.3 HEU receives CCD Low Battery Charge Exception Cleared message

The HEU shall include the CCD that cleared the Low Battery exception as an operative brake unless another fault prevents this.

2.4.8.4 HEU detects EOT node low battery charge

The HEU shall detect an EOT node low battery charge. On detection of an EOT node low battery charge, the HEU shall command a full-service brake application and provide a warning to the engineer. The HEU shall detect an EOT node low battery charge based on information in the EOT node beacon.

2.4.8.4.1 HEU receives EOT Node Low Battery Charge Exception Cleared message

The HEU clears the fault when an EOT node Low Battery Charge Exception Clear message is received, the EOT beacon indicates charged battery or the train mode is changed.

2.4.9 PSC or EOT node detects greater than 30 V when power is off

Allowing for a 10 d settling period after the HEU beacon power flag is set to OFF, if the trainline voltage monitored by a PSC or the EOT node is greater than 30 VDC ±4 percent, then the PSC or EOT node shall transmit a High Trainline Voltage exception message to the HEU.

2.4.9.1 Clearing PSC or EOT node detects greater than 30 V when power is off

If the trainline voltage detected by the PSC or EOT node with an active High Trainline Voltage exception is less than 10 VDC ±4 percent or the HEU beacon power flag is set to ON, then the PSCs or EOT node shall transmit a High Trainline Voltage Exception Cleared message to the HEU.

2.4.9.2 HEU receives PSC or EOT node detects greater than 30 V when power is off

If the HEU receives a High Trainline Voltage exception message from a PSC or EOT node, then it shall visually and audibly warn the engineer that the trainline voltage is not off. This shall be an acknowledged warning. An indication that the trainline voltage is still on shall remain displayed until the PSCs and/or EOT node indicate trainline power is off.

2.4.10 CCD detects incorrect BC pressure or stuck brake

If a CCD determines that it is unable to control the BCP for any of the following conditions, it shall generate an Incorrect BC Pressure exception message.

- CCD detects a BCP that for non-zero TBC is 10 psig or more higher than the target BCP (BCP High)
- CCD cannot obtain a BCP of at least 5 psig after minimum service or greater is commanded (BCP Cannot Apply). A CCD with this condition may automatically cut out
- CCD cannot release BCP below 5 psig with a TBC = 0 (BCP Stuck Brake)
- Other conditions as determined by the manufacturer

If the CCD is cut in and the incorrect BCP is due to a BCP stuck brake, the CCD shall generate an Incorrect BCP exception message every 60 s as long as the BCP Stuck Brake condition still exists (see Section 2.4.10.2, “HEU receives CCD Incorrect BCP Exception or Stuck Brake exception.”

If the CCD is cut out and the incorrect BCP is due to a BCP stuck brake, then the CCD shall generate a BCP Stuck Brake exception every 60 s as long as the BCP Stuck Brake condition still exists (see Section 2.4.10.2, "HEU receives CCD Incorrect BCP Exception or Stuck Brake exception."

The Incorrect BCP exception and the BCP Stuck Brake exception messages shall include the actual BCP (in psig), the target BCP (in psig), current reservoir pressure and an indication from the CCD of the reason for incorrect BCP. With the exception of the condition noted previously (BCP Cannot Apply), a CCD shall not automatically cut out as a result of detecting incorrect BCP.

2.4.10.1 Clearing CCD Detects Incorrect BC Pressure exception or Stuck Brake exception

If a CCD determines that it has regained control of the BCP, it shall transmit an Incorrect BC Pressure Exception or BCP Stuck Brake Exception Cleared message. The engineer then has the option to cut in the CCD.

2.4.10.2 HEU receives CCD Incorrect BCP exception or Stuck Brake exception

If the HEU receives an Incorrect BCP exception due to BCP Stuck Brake or BCP High from a CCD, then the HEU shall automatically command the CCD to cut out in accordance with the limitations of Section 2.3.12.1.

If the HEU receives a BCP Stuck Brake exception, the HEU shall warn the engineer. This warning shall clearly indicate that the condition is a BCP stuck brake and that the car requires it to be manually cut out and pneumatically drained of all air. This warning may be repeated in accordance with Section 2.3.12.3.

Upon receiving an Incorrect BCP exception, the HEU shall warn the engineer of the condition, which shall clearly indicate the condition as either a BCP High, BCP Cannot Apply or BCP Stuck Brake. If it is determined by the engineer that the CCD has failed, then the engineer can command the CCD to cut out. See Section 2.3.12, "CCD cut-out/cut-in."

2.4.11 Device detects multiple lead (active) HEUs in network

The lead locomotive equipment shall determine if there are multiple lead HEUs on the train. Within 10 s of first detecting this condition, the lead HEU shall respond in the same manner as when it receives a multiple lead HEU exception from a trailing device (Section 2.4.11.1).

Other devices including a trailing HEU, PSC, CCD or EOT device may additionally determine that there are multiple lead HEUs on the train, and if detected, shall report a Multiple Lead HEU exception message.

2.4.11.1 HEU detects or receives Multiple Lead HEU exception

Upon detection of a Multiple Lead HEU condition or receipt of a Multiple Lead HEU exception message, the lead HEU shall broadcast HEU beacons with the mode set to Initialization and a TBC of 100 percent and then transition to the trail state.

2.4.12 Other local fault detected

If a network device detects a fault not listed above, it may send an exception message to the HEU in accordance with APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems." The HEU shall log these exception messages for display on system diagnostic screens. High-priority exception messages (e.g., Hot Bearing Detected, Wheels on the Ground, Severe Truck Hunting, Severe Harmonic Rocking, Stuck Hand Brake) as defined in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems," shall be displayed to the engineer.

Example exception messages that would appear only on diagnostic screens and be saved in an event recorder could include the following:

- CCD System Self-Diagnostic Test Fails
- Trailing HEU Not Sending Status Messages
- Car Sensor Detects Worn Brake Shoes

2.4.12.1 CCD detects car ID fault

The CCD shall generate a car ID fault and cut out if it detects a default or incorrect car static data.

2.4.13 Recovery from emergency, fault-induced or penalty brake applications

In all cases, an ECP brake system fault-induced full-service or full-service-penalty application shall stay in effect for 60 s or until the train has stopped and the penalty source has cleared. An ECP electronic emergency shall remain in effect for a minimum of 60 s. After the cause has been eliminated, the HEU shall provide a means for the engineer to release the interlock. Releasing the interlock shall cause an HEU that has a 120 percent application to transition to 100 percent application, or an HEU that has a 100 percent application to remain at 100 percent application, where subsequent brake controller operation shall again be permitted.

2.4.13.1 Process at locomotive for recovery from emergency, fault-induced or penalty brake applications

2.4.13.1.1 In order to recharge brake pipe after a pneumatic emergency, the locomotive's train brake handle shall be required to be moved to the Release position. A prompt shall be displayed to the train operator stating that in order to charge brake pipe the train brake handle is to be moved to the Release position. The TBC will remain at 120 percent, and the operable cars will not release brakes.

In order to recharge BP after a pneumatic emergency, BP shall be allowed to charge to release pressure when the automatic brake handle has been moved into the service zone (or Release).

> **NOTE:** Once BP has charged, brakes will gradually release in response to handle movement.

2.4.13.1.2 In order to clear an ECP brake interlock on locomotives where the TBC is controlled by the locomotive's train brake handle, the train brake handle shall be required to be moved to the full-service position. A message shall be displayed to the train operator stating that the train brake handle is to be moved to the full-service position to clear the ECP brake interlock. If the handle is moved out of the full-service position before the ECP recovery conditions are met, then a message shall be displayed to the train operator to move the train brake handle back to the full-service position.

2.4.13.1.3 If the train brake handle is in the full-service position and the ECP recovery conditions are met, then the ECP brake interlock shall clear without any other operator action. This will result in a TBC of 120 percent to transition to 100 percent, or a TBC of 100 percent to remain at 100 percent (until a different TBC is then requested).

2.4.13.1.4 The display shall provide an indication of the time remaining until the ECP emergency timer expires.

2.4.13.1.5 On locomotives that are equipped with an ECP TBC control device separate from the train brake handle, a means of allowing the engineer to take an action to clear the ECP brake interlock while leaving the train brake handle in release shall be provided.

2.5 Communications crosstalk mitigation

The ECP-equipped train's devices communicate via a local area network. Each device is connected using the trainline as a single common communications medium. In general, communication between trains is unlikely; however, certain hardware fault conditions (such as trainline ground faults) can result in some messages being exchanged between trains. This inadvertent communication is called a crosstalk event.

The following sections define the requirements related to mitigating the effects of crosstalk events. These methods define how devices on the trainline establish a logical connection with a single lead HEU and filter messages originating from another train.

The lead HEU connection functions are defined in Section 2.5.1. These functions establish a method for a trailing device to make a connection with the lead HEU. The message filtering functions are defined in Section 2.5.2. These functions establish the criteria for determining which messages devices in the train should process and which are due to crosstalk and should be ignored.

2.5.1 Lead HEU connection

The purpose of the lead HEU connection function is to create a logical connection between the lead HEU and other devices in the train. Prior to making a connection with the lead HEU, CCDs and trailing HEUs shall not generate exceptions or respond to brake commands and system queries. PSCs and EOT nodes are required to perform some limited trainline communications prior to making a connection with the lead HEU.

2.5.1.1 Train ID

The Train ID is a value transmitted in the HEU beacon that is intended to identify the current lead locomotive and distinguish it from other locomotives. The Train ID is defined in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

The Train ID is also used in messages from the trailing HEUs, PSC, CCD and EOT node to indicate to other devices which lead locomotive it is connected with.

2.5.1.2 Connection with a lead HEU

A trailing device shall connect with a lead HEU when it is *not* connected to another lead HEU. Trailing devices establish a connection with a lead HEU based on trainline power being recently present and having received multiple HEU beacons with the same source address and Train ID. If crosstalk is present and HEU beacons are being received from multiple sources, then a connect flag in the HEU beacon shall be used to determine which lead HEU to connect with.

The EOT node shall transmit EOT beacons while it is in the unconnected state.

The PSC shall temporarily connect with a lead HEU for purposes of determining available PSCs and establishing trainline power.

After a device has connected with the lead HEU, it shall filter received messages as indicated in Section 2.5.2.

2.5.1.3 Disconnecting from a lead HEU

Devices connected to a lead HEU shall disconnect from the lead HEU when the following three conditions have been met:

1. No HEU beacons are being received from the connected HEU.
2. Trainline power has been off and then reapplied for at least 3 s.
3. An HEU beacon from a different HEU has been received.

2.5.2 Message filtering

The purpose of the message filtering function is to allow devices connected to a lead HEU to filter messages from other devices that may be received as a result of a crosstalk event.

2.5.2.1 HEU beacon filtering

When connected to a lead HEU, a trailing device shall ignore HEU beacons received with a different Train ID than the Train ID it is connected with and shall indicate in its status message that a crosstalk event has occurred.

2.5.2.2 Critical Loss exception filtering

When connected to a lead HEU, a trailing device shall ignore Critical Loss exceptions received with a different Train ID than the Train ID it is connected with and shall indicate in its status message that a crosstalk event has occurred.

2.5.2.3 EOT beacon filtering

The lead HEU shall process EOT beacons that have the same Train ID as the lead HEU.

For purposes of initially establishing trainline power, the lead HEU shall also process EOT beacons that are not yet connected to any lead HEU.

2.5.2.4 Query and command filtering

When connected to a lead HEU, a trailing device shall ignore query and command messages received from devices other than its connected lead HEU or a standard tool (Section 2.5.2.6).

2.5.2.5 Response and exception filtering

The lead HEU shall ignore any messages destined for other lead HEUs.

The lead HEU shall ignore response messages received from devices other than the device currently being queried or polled by the lead HEU.

2.5.2.6 Installation tool messages

All devices shall respond to commands and queries from a standard tool address. The standard tool addresses are specified in the APTA PR-M-S-024-19, latest revision, “Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems.”

3. Environmental requirements

The passenger ECP system shall comply with the vibration, temperature and humidity requirements specified in PRIIA documents 305-912 and 305-916.

4. Approval procedure

The approval procedure will be addressed in a future ECP standard.

5. Interoperability between freight and passenger rail

1. When setting up ECP, the operator must select passenger or freight mode of operation.
2. The selected freight or passenger mode will be broadcast to all the devices on the train.
3. Trailing passenger devices shall respond accordingly to the selected operating mode.

NOTE: When operating in freight mode, all braking will follow the freight ECP braking performance.

Related APTA standards

APTA PR-M-S-005-98, Rev. 4, "Code of Tests for Passenger Car Equipment Using Single Car Testing"
APTA PR-M-S-020-17, Rev. 1, "Passenger Electronic 26C Emulation Braking System – Performance Requirements"

The following standards are the complete set of Passenger ECP standards:

APTA PR-M-S-020-17, "Passenger Electronic 26C Emulation Braking System—Performance Requirements"
APTA PR-M-S-021-17, "ECP Passenger Cable-Based Braking System—Performance Requirements"
APTA PR-M-S-022-19, "ECP Passenger Cable-Based Brake System Cable, Connectors and Junction Boxes—Performance Requirements"
APTA PR-M-S-023-19, "ECP Passenger Cable-Based Brake DC Power Supply—Performance Requirements"
APTA PR-M-S-024-19, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems"
APTA PR-M-S-025-19, "ECP Passenger Cable-Based and Passenger Emulation Braking System—Approval Procedure"
APTA PR-M-S-026-19, "ECP Passenger Cable-Based Braking System—Interoperability Procedure"
APTA PR-M-S-027-19, "ECP Passenger Cable-Based Braking System—Configuration Management"

References

AAR Manual of Standards and Recommended Practices:
S-401, "Freight Brake Design Requirements"
S-4200 (2014), "Electronically Controlled Pneumatic (ECP) Cable-Based Brake Systems – Performance Requirements"

Federal Communications Commission, FCC Part 15, Section 15.107

Definitions

backup battery: The battery source that is part of the CCD and is used to power the system when the trainline power and the local car battery power are not present.

cab car: The car providing controlling functions to remotely operate a trail locomotive and to provide braking and traction commands. The ECP components of a cab car include elements of both HEU and CCD functionality.

car control device (CCD): An electronic control device that replaces the function of the conventional pneumatic service and emergency portions during electronic braking and provides for electronically controlled service and emergency brake applications. The CCD interprets and acknowledges the electronic signals and controls the service and emergency braking functions on the car. In a standalone system, the CCD also controls reservoir charging. The CCD also will send a warning signal to the locomotive in case any of the components cannot respond appropriately to a braking command. Each CCD has a unique electronic address that is keyed to car reporting marks and number. A CCD shall be activated by presence of trainline power. Each CCD contains a battery, which is charged from trainline power.

car ID module: Car-specific data shall be stored in a module on the car and provided to the CCD in such a way that the CCD always contains the correct characteristics, parameters (constants) and other information for the car or brake set on which it is placed. Therefore, car-specific data shall be mechanically tied to the car in such a way that it cannot be changed inadvertently in the field, even if CCDs are swapped. Format of the car-specific data is given in APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for

ECP Cable-Based Passenger Train Control Systems.” The CCD shall maintain a copy of the car ID information. At a minimum, this information shall contain the following:

- Vehicle reporting mark
- AAR car type
- Stretched length over pulling faces
- Loaded weight
- Empty weight
- Default full-service net braking ratio (NBR)
- Braking constant “C”
- Reservoir constant “RC”
- Minimum brake application cylinder pressure
- Presence/type of pneumatic empty/load device
- Presence of electronic empty/load device
- Number of operable brakes controlled
- Number of axles associated with CCD
- Vehicle orientation reference

ECP brake (trainline) DC power supply: The ECP brake system power supply is a DC supply operating at nominally 230 VDC to provide electrical power, via the trainline, to all connected CCDs and EOT devices. The power supply is mounted within a locomotive and is controlled by a power supply controller (PSC), which is a network device. The power supply shall meet the requirements of APTA PR-M-S-023-19, latest revision, “ECP Passenger Cable-Based Brake DC Power Supply—Performance Requirements.” A single power supply shall be capable of supplying power to an ECP-equipped train consisting of a minimum of 160 CCDs and an EOT node.

emulation mode: Non-ECP mode of operation in which the electronic pneumatic components emulate the performance of the 26C control valve and follow the brake pipe for determining brake cylinder pressure.

end-of-train (EOT) node: The EOT node is physically the last network node in the train and transmits a status message (EOT beacon) once per second. The status message includes the current brake pipe pressure that is displayed in the cab by the HEU. If the EOT does not require an emergency brake pipe vent valve, the hose to the EOT node shall be a minimum of ⅜ in. ID. The EOT node also shall contain an electric trainline termination circuit. This termination circuit shall be a 50-ohm resistor in series with a 0.47 µF capacitor. The EOT node shall be connected to the network and shall be transmitting status messages to the HEU before the trainline power can be energized continuously. The EOT node continually reports brake pipe pressure and trainline voltage to the HEU. An EOT node shall be activated by the presence of trainline power. The requirements defined herein are those EOT node functions required for ECP braked trains. The EOT node is an electronic logic circuit representing a train termination point. An EOT node can represent one of three physical forms:

- An ECP EOT device
- An enabled ECP locomotive or cab-car
- An enabled ECP coach car

end-of-train (EOT) device: An item that is connected to the trainline at the end of the train that contains a means of communicating with the HEU, a brake pipe pressure transducer, and a battery that charges off the trainline cable. The EOT device is physically the last network node in the train and transmits a status message (EOT beacon) once per second. The status message includes the current brake pipe pressure that is displayed in the cab by the HEU. If the EOT does not require an emergency brake pipe vent valve, then the hose to the

EOT device shall be a minimum of ⅜ in. ID. The EOT device also shall contain an electric trainline termination circuit. This termination circuit shall be a 50 ohm resistor in series with a 0.47 µF capacitor. The EOT device shall be connected to the network and shall be transmitting status messages to the HEU before the trainline power can be energized continuously. The EOT device continually reports brake pipe pressure and trainline voltage to the HEU. An EOT device shall be activated by the presence of trainline power. The requirements defined herein are those EOT device functions required for ECP braked trains. The ECP EOT device may be a device separate from the EOT device specified for pneumatically braked trains in the AAR Communication Manual, Parts 12–15. For ECP trains capable of operating in a pneumatic mode (overlay or emulator brake systems), a pneumatic EOT device function also shall be required. The ECP EOT device functions may be combined in a single, dual-mode device with the pneumatic EOT device functions. A dual-mode EOT device shall meet the requirements defined herein for ECP operation and the requirements for pneumatic EOT devices specified in the AAR Communications Manual, Parts 12–15, and all applicable FRA rules. ECP equipment on a locomotive at the end of the train may perform the ECP EOT device function. Locomotive ECP equipment functioning as an EOT device shall meet the requirements defined in this standard. An ECP EOT device that does not also provide radio functionality does not require the annual calibration that is required of the EOT device specified for pneumatically braked trains in the AAR Communication Manual, Parts 12–15.

head end trainline terminator: A terminator shall be attached to the front of the trainline that provides an electrical termination of the trainline at the lead locomotive to minimize impedance-related communications faults. This termination circuit shall be a 50 ohm resistor in series with a 0.47 µF capacitor. The HEU shall automatically confirm the presence of the head end trainline termination. If the termination includes an ITC network device, then it shall be incapable of transmitting.

head end unit (HEU): A brake system control device mounted within the locomotive and used to control the ECP brake system. The following are the specific functions of the HEU:

- Provide a human-machine interface to operate the ECP brake system
- Provide a data display to the engineer
- Provide controls that allow the engineer to make brake commands
- Monitor the EOT beacon
- Provide a control signal to turn off trainline power whenever communication with the EOT is interrupted or discontinued
- Provide a control signal to command a momentary trainline power application to restart CCDs that are shut down
- Provide mechanisms to conduct ECP brake system diagnostic tests
- Interface with locomotive system signals that interact with the train braking system
- Interface with the locomotive ID module in order to obtain locomotive-specific data
- Provide an interface to other locomotive system(s) with the intent of being able to provide appropriate locomotive retardation in conjunction with ECP train braking

locomotive ID module: The module designated for storing locomotive-specific data on the locomotive. The locomotive ID module shall provide data for the HEU and PSC in such a way that the HEU and PSC always contain the correct characteristics, parameters (constants) and other information for the locomotive on which they are placed. The locomotive-specific data shall be mechanically tied to the locomotive such that it cannot be changed inadvertently in the field even if the HEU or PSC is replaced. Format and resolution of the locomotive-specific data are given APTA PR-M-S-024-19, latest revision, “Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems.” At a minimum, this information shall contain the following:

- Locomotive road number
- Locomotive type
- Stretched length
- Nominal weight
- Number of axles
- Battery voltage fault threshold
- Battery voltage fault clear threshold
- Railroad default BBP set point
- Default train full-service NBR
- Suppression brake application
- Nominal wheel diameter
- Vehicle orientation reference

load weigh: Local adjustment of brake cylinder pressure based on the current weight of the vehicle.

local car battery: Battery power source provided by the passenger car backup battery. This term is used to differentiate it from the backup battery, which is an integral part of the CCD.

operative brake: An individual brake set that is fully functional. One brake set is two braked trucks.

passenger ECP EOT: The passenger ECP EOT performs similar functions as the freight ECP EOT with the following exceptions:

- The EOT is not required to monitor the brake pipe.
- The EOT is not required to include a marker light.
- The EOT is not required to detect motion.

pneumatic backup (PB): A system required on each car to apply emergency brake cylinder pressure in the event of a vented brake pipe. The PB system also shall be capable of assisting in propagating pneumatic pressure signals through the brake pipe.

power supply controller (PSC): The controller that interfaces with the trainline communication network and controls a trainline power supply as commanded by the HEU. Multiple power supplies may be enabled by the HEU, as described in this standard. The PSC shall also comply with the requirements of APTA PR-M-S-023-19, latest revision, "ECP Passenger Cable-Based Brake DC Power Supply—Performance Requirements," and APTA PR-M-S-024-19, latest revision, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems."

snow brake: A means of applying a light brake cylinder pressure on a vehicle to prevent the accumulation of ice and snow between the friction material and the braking surface.

trainline: A two-conductor electric wire spanning the train that carries both trainline power (to operate all CCDs and EOT devices) and communications network signals (superimposed on the power voltage). The trainline shall meet the requirements of APTA PR-M-S-022-19, latest revision, "ECP Passenger Cable-Based Brake System Cable, Connectors and Junction Boxes—Performance Requirements."

trainline termination plug: A device that may be used in place of an ECP EOT to allow trainline power to remain on continuously.

Abbreviations and acronyms

A	amperes
μF	microfarads
AAR	Association of American Railroads
BCP	brake cylinder pressure
BP	brake pipe
BP	brake pipe pressure
CCD	car control device
CRDC	car control device
dB	decibels
dBμV	decibels relative to 1 microvolt
EAB	electronic air brake
ECP	electronically controlled pneumatic
EOT	end of train
h	hours
HEU	head end unit
kHz	kilohertz
mA	milliampere
MHz	megahertz
min	minutes
MSP	minimum service pressure
MU	multiple unit
NATSA	North American Transportation Services Association
NBR	net braking ratio
PB	pneumatic backup
PBA	percentage brake applied
PRIIA	Passenger Rail Investment and Improvement Act (2008)
PSC	power supply controller
psi	pounds per square inch
psig	pounds per square inch gauge
PTC	positive train control
s	seconds
TBC	train braking command
TBE	train braking effort
TPS	trainline power supply
VDC	voltage direct current
W	watts

Summary of document changes

- Section 2.2: Added Emulation mode requirement.
- Section 2.2.2.1: Lowered full-service application timespan from 120 to 60 s to reflect better passenger consists.
- Section 2.2.4.3: Removed CCD requirement.
- Section 2.2.5.3.1.3: Moved "Low EOT BP" from under "Warning only" to under "Automatic full service."
- Section 2.2.5.4: Changed purpose of trainline plug from allowing ECP operation to allowing maintenance and fault isolation.
- Section 2.3.1.1: Combined 8 and 9.
- Section 2.3.3.3.2: Minor wording change to better reflect function of PSCs.

- Section 2.3.12.1: Removed “SWITCH mode” cut-out characteristics as it is not automatic.
- Section 2.3.13.1: Added qualifier of local car battery power to line power failure.
- Section 2.3.13.4: Removed, as it was a duplicate of Section 2.3.13.1.
- Table 3: Changed “operative brakes detected” to reflect Sections 2.4.5.1 and 2.4.5.2.
- Updated references.
- Definitions: Defined “EOT node,” formerly referred to as “EOT.”
- Definitions: Differentiated between “EOT node” and “EOT device.”
- Definitions: Removed SWITCH mode from definition of “trainline termination plug.”
- Abbreviations and acronyms: Added A, μF, dB, dBμV, h, KHz, mA, min, MHz, MSP, MU, NATSA, NBR, PB, PBA, PSC, psig, s, TBC TBE and TPS.
- New section added: “Summary of document changes.”
- Corrected standard titles to APTA format requirements

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